

# **Historic, Archive Document**

Do not assume content reflects current  
scientific knowledge, policies, or practices.





a SD11  
A 42

Reserve

United States  
Department of  
Agriculture

Forest Service

Rocky Mountain  
Forest and Range  
Experiment Station

Fort Collins,  
Colorado 80526

General Technical  
Report RM-181

cost / unit (S)

# An Analysis of the Land Base Situation in the United States: 1989-2040

A Technical Document Supporting the  
1989 USDA Forest Service RPA Assessment



## Preface

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 88 Stat. 475, as amended, directed the Secretary of Agriculture to prepare a Renewable Resources Assessment by December 31, 1975, with an update in 1979 and each 10th year thereafter. This Assessment is to include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis on pertinent supply, demand and price relationship trends" (Sec. 3.(a)).

The 1989 RPA Assessment is the third prepared in response to the RPA legislation. It is composed of 12 documents, including this one. The summary Assessment document presents an overview of analyses of the present situation and the outlook for the land base, outdoor recreation and wilderness, wildlife and fish, forest-range grazing, minerals, timber, and water. Complete analyses for each of these resources are contained in seven sup-

porting technical documents. There are also technical documents presenting information on interactions among the various resources, the basic assumptions for the Assessment, a description of Forest Service programs, and the evolving use and management of the Nation's forests, grasslands, croplands, and related resources.

The Forest Service has been carrying out resource analyses in the United States for over a century. Congressional interest was first expressed in the Appropriations Act of August 15, 1876, which provided \$2,000 for the employment of an expert to study and report on forest conditions. Between that time and 1974, Forest Service analysts prepared a number of assessments of the timber resource situation intermittently in response to emerging issues and perceived needs for better resource information. The 1974 RPA legislation established a periodic reporting requirement and broadened the resource coverage from timber to all renewable resources from forest and rangelands.

USDA Forest Service  
General Technical Report RM-181

October 1989

# **An Analysis of the Land Base Situation in the United States: 1989–2040**

## Acknowledgments

This study is the product of many people, most of whom are employees of the USDA Forest Service. The names of principal and substantive contributors to the individual chapters are listed below. Without the help of these and other support personnel this document would not have been possible. Their contribution is gratefully acknowledged.

The principal authors of Chapter 1, The National Overview, were James T. Bones, Ann E. Carey, Linda A. Joyce, and Edward F. Schlatzterer. Key statistics on the forest resource were compiled by Daniel D. Oswald and Karen Waddell from the RPA national data base.

The principal authors of Chapter 2, The North and Great Plains, were Thomas W. Birch and John S. Spencer, Jr.

The principal authors of Chapter 3, The South, were William H. McWilliams and Raymond M. Sheffield.

The principal authors of Chapter 4, The Rocky Mountains, were Alan W. Green and Renee A. O'Brien.

The principal authors of Chapter 5, The Pacific Coast, were Charles L. Bolsinger and Willem W. S. van Hees.

The principal authors of Chapter 6, Other Resources of the Land Base, were James T. Bones, John O. Nordin, and William E. Shands (Conservation Foundation).

The principal author of Chapter 7, Projecting Land Cover and Use Changes, was Ralph J. Alig. Assistance in preparing input for the chapter was provided by William G. Hohenstein, Brian C. Murray, and Robert G. Haight. Additional data and consultation was provided by the Forest Inventory and Analysis research work units.

General planning and direction of the study were provided by James T. Bones. John S. Spencer, Jr. contributed significantly by organizing and revising the text. Mary D. Williams provided the primary support for preparation of the text.

## Contents

	<b>Page</b>
<b>HIGHLIGHTS</b> .....	v
<b>CHAPTER 1: NATIONAL OVERVIEW</b>	
Vegetation Cover .....	1
Range and Forest Land Vegetation Base .....	1
Eastern Forest Ecosystems .....	3
Western Forest Ecosystems .....	7
Grassland and Shrubland Ecosystems .....	8
Ownership .....	10
Forest Land Productivity .....	12
Rangeland Condition .....	12
Water Areas .....	14
Environmental Health .....	15
Atmospheric Deposition .....	15
Sources and Types .....	15
U.S. Distribution .....	16
Forest Declines .....	17
Forest Effects Research .....	18
<b>CHAPTER 2: THE NORTH AND THE GREAT PLAINS</b>	
Location and Characteristics .....	19
Forest Land .....	19
Ecosystems .....	19
Ownership .....	21
Productivity .....	22
Use .....	22
Trends in Forest Area .....	23
Rangelands .....	24
Water Areas .....	24
<b>CHAPTER 3: THE SOUTH</b>	
Location and Characteristics .....	25
Forest Land .....	26
Ecosystems .....	26
Ownership .....	28
Productivity .....	28
Use .....	29
Trends in Forest Area .....	29
Rangelands .....	30
Water areas .....	31
<b>CHAPTER 4: THE ROCKY MOUNTAINS</b>	
Location and Characteristics .....	32
Forest Land .....	32
Ecosystems .....	33
Timberland .....	33
Woodland .....	34
Ownership .....	34
Productivity .....	34
Use .....	34
Trends in forest area .....	35
Rangelands .....	35
Ecosystems .....	35

	Page
Woodland .....	35
Shrubland .....	36
Grassland .....	36
Ownership .....	37
Productivity .....	37
Use .....	37
Trends in Rangeland Area .....	37
Water Areas .....	37
<b>CHAPTER 5: THE PACIFIC COAST</b>	
Location and Characteristics .....	38
Forest Land .....	38
Ecosystems .....	39
Mainland Hardwoods .....	40
Hawaiian Islands .....	41
Ownership, Uses, and Trends in Forest Area .....	41
Alaska .....	41
California .....	42
Oregon .....	43
Washington .....	44
Hawaii .....	46
Rangelands .....	46
Alaska .....	47
California, Oregon and Washington .....	47
Hawaii .....	49
Water Areas .....	49
<b>CHAPTER 6: OTHER RESOURCES OF THE LAND BASE</b>	
Minerals as Forest and Rangeland Resources .....	50
Energy Minerals .....	50
Metallic Minerals and Precious Metals .....	50
Non-Metallic Minerals and Minerals Materials .....	51
Location of Minerals .....	51
Ownership of Minerals .....	51
Mining on Forest and Rangelands .....	52
Reclamation of Mined Lands .....	52
Effects of Mining on Surface Resources .....	53
The Nation's Wetlands .....	54
Soil Productivity and Management .....	54
<b>CHAPTER 7: PROJECTING LAND COVER AND USE CHANGES</b>	
National Overview .....	57
Projected Forest and Range Area Changes .....	60
North and Great Plains .....	60
South .....	60
Rocky Mountains .....	62
Pacific Coast .....	62
Projected Area Changes for Forest Types .....	63
North and Great Plains .....	63
South .....	64
Rocky Mountains .....	64
Pacific Coast .....	64
Projected Changes by Site Class and Other	
Productivity Impacts .....	65
<b>REFERENCES</b> .....	65
<b>APPENDIX A—AREA PROJECTION METHODS</b> .....	72
<b>GLOSSARY</b> .....	75

## HIGHLIGHTS

### National Overview

In 1987, 1.5 billion acres, about 63% of the total land and inland water area of the United States was in forest and rangeland. Forest totals 32% and rangeland totals 34% of the land area.

Most of the Nation's forest and rangelands are in non-federal ownership. In 1987, about 1 billion acres or 67% of the total were owned by nonfederal public agencies, forest industry, farmers and ranchers, and other private individuals.

The federal lands are administered primarily by two agencies—the Forest Service and the Bureau of Land Management.

The nonfederal forest lands are concentrated in the East, and private rangelands are concentrated in the West.

Most of the Nation's high productivity forest lands are located west of the Cascade Mountains in the Pacific Northwest Region and in the South Central Region. The largest areas of highly productive sites are covered by coastal Douglas-fir and hemlock-Sitka spruce types in the West, and loblolly-shortleaf pine and oak-gum-cypress types in the East.

According to Soil Conservation Service estimates, Montana, South Dakota, and Nebraska lead all states in the area of rangeland in the excellent condition class. Texas, Arizona, and New Mexico contain the largest areas of rangeland in the poor condition class.

The area of highest acidity in rainfall for 1980-1985 is centered in western Pennsylvania, eastern Ohio, and southwestern New York. Airborne pollutants are among the suspected causes of death in high-elevation spruce, of spruce growth decreases, and of eastern and southeastern pine growth decreases.

### The North and the Great Plains

The 607.7 million acres of land in the North and Great Plains include 169.8 million acres of forest land, 28% of the total. Much of this forest land, especially in the Northeast, lies close to densely populated areas and receives intensive pressure from a wide array of forest users.

The oak-hickory ecosystem is the largest in the area with 47.8 million acres of unreserved forest land or 29% of the total. Maple-beech-birch is the second largest with 43.4 million acres, followed by spruce-fir with 18.9 million acres, aspen-birch with 17.9 million acres, white-red-jack pine with 13.5 million acres, and elm-ash-cottonwood with 11.9 million acres.

Although there is much variation among states, about 80% of all timberland in the North and Great Plains is held by private individuals or firms. Farmers own more forest land than any other group of individual owners.

The area of timberland in New England and the Middle Atlantic states increased steadily from 1952 to 1987. In the North Central Region and Great Plains Region, trends are mixed.

A total of 78.0 million acres in the North and Great Plains are classified as rangeland. Almost all is in the Great Plains. Ninety-five percent of the rangeland is in nonfederal ownership.

Water areas in the North and Great Plains total 57.8 million acres or 54% of the Nation's water. This is 8.7% of the land and water area of these two Sections.

### The South

Forest land totals nearly 200 million acres or 38% of the total land area. If the nontimbered western portions of Texas and Oklahoma are excluded, the percentage of forest increases to 54%.

The South's 62 million acres of pine forest continue as a major source of softwood fiber for the world. About two-thirds of the pine forest is natural in origin with the remainder consisting of planted pine.

Loblolly-shortleaf pine is the South's most prevalent pine ecosystem, accounting for three-fourths of the total pine forest or 46 million acres. Longleaf-slash pine totals 16 million acres and the oak-pine type covers 28 million acres.

Oak-hickory is the South's most extensive ecosystem, covering 71 million acres. Bottomland hardwood types cover 31 million acres.

Private owners control 90% of the timberland in the South, a total of 175 million acres. Nonindustrial private owners control 70% of the South's timberland, and forest industry owners control 20%.

The South has 116 million acres of rangeland, with 83% in Texas and the remainder in Oklahoma and Florida.

Water areas in the South cover 24 million acres or 4% of the total area in the section.

### The Rocky Mountains

More than 138 million acres or about 25% of the land area are occupied by forests, predominantly of softwood species. Five forest ecosystems totaling some 112 million acres make up about 80% of the forest land in the Rocky Mountain Region—pinyon-juniper, Douglas-fir, fir-spruce, ponderosa pine, and lodgepole pine.

The ponderosa pine ecosystem covers about 16.5 million acres, nearly half of which is in Arizona and New Mexico. Douglas-fir covers 17.9 million acres, principally in Idaho and Montana. Lodgepole pine covers 14.6 million acres, principally in Idaho, Montana, Wyoming, and central Colorado. Fir-spruce covers 16

million acres of higher elevation sites in the region.

Pinyon-juniper is a woodland ecosystem covering about 47 million acres of dry plateaus and broken tablelands.

Three-fourths of the forest land in the Rocky Mountain region is publicly owned. Federal agencies, principally the Forest Service, administer 94 million acres or two-thirds of the total.

The total rangeland area, including pinyon-juniper and chaparral-mountain scrub forests, is about 336 million acres or 61% of the total land base. The sagebrush type is the second largest range ecosystem in the United States with roughly 105 million acres, most of which occurs in the Rocky Mountain Region. Other important rangeland types include sagebrush, southwestern shrubsteppe, desert shrub, mountain grasslands, mountain meadows, desert grasslands, and plains grasslands.

About 167.4 million acres or 50% of the rangeland in the Rocky Mountain States is in public ownership, mostly in the care of the Bureau of Land Management.

The Rocky Mountain section has the smallest water area—roughly 6 million acres or 1% of the total geographic area.

### The Pacific Coast

Forests cover 220 million acres or 39% of the land area of the Pacific Coast states. This is 30% of all the forest land in the Nation. Productive timberland totals about 85 million acres and other forest land about 135 million acres.

Douglas-fir, the most important forest type in terms of timber production, covers about 21 million acres. It is the major type in western Oregon and western Washington.

Fir-spruce is the most extensive forest type covering about 116 million acres, mostly in Alaska's interior. Hemlock-Sitka spruce covers about 16 million acres, 11 million of which are located in southeastern Alaska.

The redwood type covers about 1.2 million acres in California. The ponderosa pine type covers about 14 million acres of the Pacific Coast, and lodgepole pine covers about 3.6 million acres.

The pinyon-juniper woodland type covers about 5 million acres, and chaparral covers about 7.6 million acres, mostly in the mediterranean climatic zone in California.

Of the 220 million acres of forest land in the 5-state area, 72 million acres are privately owned. Of the 145 million acres in public ownership, 46 million are in

national forests and 99 million acres are held by various other public agencies. Ownership of forest land in Alaska has changed dramatically in the last decade.

Alaska has about 173 million acres of rangeland, most of which is arctic and alpine tundra. California, Oregon, and Washington together have about 68 million acres of rangeland, including 23 million acres of grassland and 45 million acres of shrubland.

The Pacific Coast states contain 20.1 million acres of water, much of which is in coastal waterways.

### Other Resources of the Land Base

There is considerable uncertainty about the extent of the Nation's mineral resources. The areas of highest mineralization are the mountains and basins of the West and the Appalachian chain in the East.

Of 5.7 million acres of land disturbed for mining between 1930 and 1980, about 2.7 million acres or 47% have been reclaimed by industry.

Wetlands have high biological productivity and are important as habitat for wildlife and fish at critical times in their life cycle.

### Projecting Land Cover and Use Changes

The total area of forest and rangeland is projected to increase about 2% between 1987 and 2000, and then decrease slightly by 2040. The area of forest land is projected to decline over the projection period, decreasing by 4 percent by 2040. The projected reduction in forest land area will result mainly from conversion to other land uses such as reservoirs, urban expansion, highways, and surface mining.

The projected average annual reduction in United States forest area from 1987 to 2040, about 500,000 acres, is less than that for the period 1970 to 1987, which averaged about 2 million acres per year.

Approximately 40 to 45 million acres of highly erodible land used currently for cropland are projected to be converted to grass cover or trees under the Conservation Reserve Program by the year 2000.

In the North and Great Plains, forest and range area is projected to decline. In the Rocky Mountains, total forest and range area is expected to increase by about 15 million acres by 2040, mostly due to expansion of range area. In the Pacific Coast, forest area is projected to drop by 8 million acres and range area is expected to drop by 9 million acres by 2040.

# An Analysis of the Land Base Situation in the United States: 1989-2040

## CHAPTER 1: THE NATIONAL OVERVIEW

This chapter contains a national overview of the Nation's land base; the area and location of the forest and rangelands,<sup>1</sup> ownership characteristics, productivity, and use of these important lands that contribute so much to the Nation's wealth and well being. In 1987, 1.5 billion acres, about 63% of the total land and inland water area of the United States was in forest and rangeland (table 1). The remaining area was in cropland, deserts, barrens, improved pastures, reservoirs, and residential and urban sites including golf courses, roads, airports, shopping centers, and industrial sites.

To qualify as forest land the land must be at least 10% stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially reforested. Included are transition zones between heavily forested and nonforested lands that are at least 10% stocked with forest trees, and forest areas adjacent to urban and built-up lands.

Rangeland is land on which the potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs; including land revegetated naturally or artificially that is managed like native vegetation. Rangeland includes natural grasslands, savannas, shrublands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows that are less than 10% stocked with forest trees of any size.

Water areas include those areas that in the past have been classed as large inland water bodies such as lakes, ponds, and reservoirs greater than 40 acres in size and streams and rivers at least one-eighth of a mile wide; and small water bodies such as lakes and ponds 2 acres and greater in size and rivers and streams that are at least 120 feet wide. Also included are the Great Lakes, and the estuaries of the contiguous States, but not the estuaries of Alaska and Hawaii.

### VEGETATION COVER

The vegetation cover of the United States varies greatly and is directly related to the annual precipitation and available moisture. Those areas that receive substantial moisture are predominantly forested, while the arid and semiarid areas support grasses and shrubs and are typically associated with rangeland. The total land base of the Nation is almost evenly divided into rangeland (34%), forest land (32%) and other land (34%), which includes cropland, pasture, developed land, and barren areas (fig. 1). Most of the rangelands are found in the Nation's western states and Alaska. The following four states contain over 50 million acres of rangeland each and account for nearly half of the total range area:

	Million acres
Alaska	173
Texas	96
Nevada	60
New Mexico	51
Total	380

The Rocky Mountain Section (fig. 2) has the greatest amount of range of all the sections. A total of 336 million acres, or 61%, of the total land area is classified as rangeland. In contrast, the sections located east of the Mississippi River are mostly developed for crops or improved pasture or are heavily forested. Florida is the only eastern state with a significant amount of rangeland; but even so, its 4.4 million acres of rangeland represent only 13% of the total land area of the State (fig. 3).

Unlike rangeland, forest land is distributed widely throughout the entire United States. Land east of the Great Plains that has not been cleared for agriculture or other works of man is heavily forested. The high elevation areas of the West that receive ample precipitation and the humid portions of the Pacific Coast are also forested. Aside from the Great Plains and the agriculturally important portions of the central states, forests make up an important component of the vegetation of the Nation (fig. 4). Nebraska and North Dakota currently have the lowest percentage of forest cover (each 1%) and Maine has the highest (90%).

### RANGE AND FOREST LAND VEGETATION BASE

Vegetation on range and forest land is a function of the climate, fauna, and soils within the landscape. Classification systems have been developed to describe the diversity of vegetation across the Nation's landscape (Bailey 1978, Garrison et al. 1977, Kuchler 1964). In this document, vegetation on forest and rangeland will be described using the 34 ecosystems of the Forest and Range Environmental System (FRES) (Garrison et al. 1977). Forest ecosystems in this system are aggregations of Forest Service forest types (USDA Forest Service 1967). Throughout this paper the term "forest ecosystem" is synonymous with "forest type." Forest Service Forest Inventory and Analysis Work Units throughout the Nation classify forest land by forest type as part of ongoing state inventories. This classification is based on the tree species that presently occupy the site, rather than on potential species. Rangeland ecosystems are broad groupings of the potential natural vegetation (PNV) communities developed by Kuchler (1964). PNV is the vegetation that would exist at a site today if humans or their impact were removed. The vegetation type, mountain meadow, an

<sup>1</sup>See Glossary for definition of terms.

Table 1.—Land and water areas (thousand acres) of the United States, by section, region, and state, 1987

Section, region, and state	Total land and water area	Land				Total water area <sup>2</sup>
		Forest and rangeland		Other land		
		Total	Forest <sup>1</sup>	Range- land		
North						
Northeast						
Connecticut	3,575	3,090	1,815	1,815	—	1,275
Delaware	1,512	1,206	398	398	—	808
Maine	21,968	19,732	17,713	17,713	—	2,019
Maryland	7,797	6,252	2,632	2,632	—	3,620
Massachusetts	5,942	4,994	3,097	3,097	—	1,897
New Hampshire	5,926	5,701	5,021	5,021	—	680
New Jersey	5,148	4,648	1,985	1,985	—	2,663
New York	34,421	30,273	18,791	18,775	16	11,482
Pennsylvania	29,456	28,601	16,997	16,997	—	11,604
Rhode Island	782	667	399	399	—	268
Vermont	6,171	5,915	4,479	4,479	—	1,436
West Virginia	15,508	15,406	11,942	11,942	—	3,464
Total	138,206	126,486	85,269	85,253	16	41,216
North Central						
Illinois	37,102	35,531	4,265	4,265	—	31,266
Indiana	23,269	22,895	4,439	4,439	—	18,456
Iowa	35,968	35,746	1,565	1,562	3	34,181
Michigan	62,122	36,362	18,220	18,220	—	18,142
Minnesota	55,369	50,640	16,874	16,583	291	33,766
Missouri	44,684	44,123	12,632	12,523	109	31,491
Ohio	28,615	26,211	7,309	7,309	—	18,902
Wisconsin	42,391	34,740	15,326	15,319	7	19,414
Total	329,520	286,247	80,630	80,220	410	205,618
North Total	467,726	412,733	165,899	165,473	426	246,834
South						
Southeast						
Florida	39,000	34,533	21,110	16,721	4,389	13,423
Georgia	37,734	36,837	23,907	23,907	—	12,930
North Carolina	33,704	30,990	18,891	18,891	—	12,099
South Carolina	19,986	19,077	12,257	12,257	—	6,820
Virginia	27,038	25,246	15,968	15,968	—	9,278
Total	157,461	146,682	92,133	87,744	4,389	54,549
South Total	557,733	534,395	319,239	203,485	115,754	215,154
Rocky Mountains and Great Plains						
Rocky Mountains						
Arizona	72,930	72,607	66,648	19,384	47,264	5,959
Colorado	66,693	66,249	49,199	21,338	27,861	17,050
Idaho	53,493	52,692	43,717	21,818	21,899	8,975
Montana	94,064	92,765	71,119	21,910	49,209	21,646
Nevada	70,581	70,112	69,231	8,928	60,303	881
New Mexico	77,845	77,632	69,652	18,526	51,126	7,980
Utah	54,343	52,502	48,331	16,234	32,097	4,171
Wyoming	62,711	62,055	56,025	9,966	46,059	6,030
Total	552,660	546,614	473,922	138,104	335,818	72,692

Table 1.—Continued

Section, region, and state	Total land and water area	Total land area	Land			Other land	Total water area <sup>2</sup>
			Total	Forest and rangeland	Range- land		
Great Plains							
Kansas	52,636	52,228	17,998	1,358	16,640	34,230	408
Nebraska	49,467	49,005	24,565	722	23,843	24,440	462
North Dakota	45,287	44,271	13,143	460	12,683	31,128	1,016
South Dakota	49,462	48,532	26,101	1,687	24,414	22,431	930
Total	196,852	194,037	81,807	4,227	77,580	112,229	2,816
Rocky Mountains and Great Plains Total	749,512	740,651	555,729	142,331	413,398	184,921	8,862
Pacific Coast							
Pacific Northwest							
Alaska	378,243	361,887	301,780	129,045	172,735	60,107	16,356
Oregon	62,225	61,546	50,086	28,055	22,031	11,460	679
Washington	43,669	42,483	29,378	21,856	7,522	13,105	1,186
Total	484,137	465,916	381,244	178,956	202,288	84,672	18,221
Pacific Southwest							
California	101,616	99,773	77,868	39,381	38,487	21,905	1,843
Hawaii	4,146	4,110	1,748	1,748	( <sup>3</sup> )	2,362	36
Total	105,762	103,884	79,616	41,129	38,487	24,267	1,879
Pacific Coast Total	589,899	569,800	460,860	220,085	240,775	108,939	20,100
United States Total	2,364,870	2,257,578	1,501,727	731,374	770,353	755,847	107,293

<sup>1</sup>Contains transition lands that meet the definition of forest land based on cover characteristics but where the predominant vegetation is grasses and forb plants that are used for grazing. The Soil Conservation Service has classified and reported most of these lands as rangeland. In most cases these are noncommercial timberland ecosystems such as pinyon-juniper, chaparral, and post oak.

<sup>2</sup>Includes Atlantic, Pacific, and Gulf Coastal waters; Chesapeake and Delaware Bays; Long Island and Puget Sounds; New York Harbor; Straits of Juan de Fuca and Georgia; and the Great Lakes. Excludes Alaska and Hawaii.

<sup>3</sup>No estimate of rangeland area in Hawaii was available at the time this table was assembled. A current estimate, however, is 1.4 million acres.

Note: Data may not add to totals because of rounding.

Sources: Rangeland areas—Forest Service—Soil Conservation Service reconciled figures, 1982. Forest land areas—Forest Service RPA data base, 1987.

important type for livestock grazing, was added to Kuchler's system. This amended classification was renamed Potential Natural Communities (PNC) to mark this distinction from Kuchler's system (Mitchell and Joyce 1986).

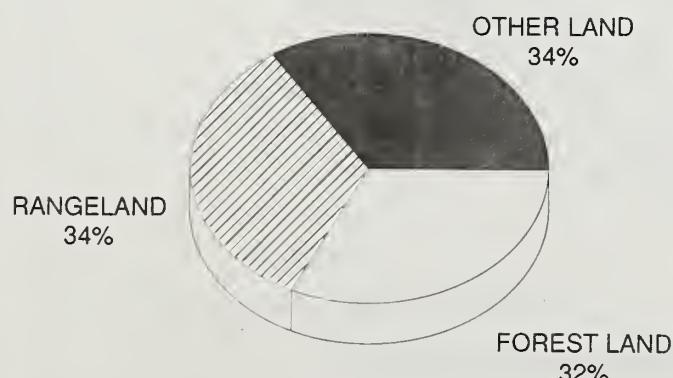


Figure 1.—Distribution of land by use in the United States, 1987.

A brief description of the FRES ecosystems follows.<sup>2</sup> The broad geographic locations are shown within the United States in fig. 5, and defined in table 2. The description of each ecosystem is taken from Garrison et al. (1977) unless otherwise referenced. More detailed information on fauna found on the Nation's forest and rangelands can be found in Flather (in press), and on timber products from forest lands in Haynes (in press).

### Eastern Forest Ecosystems

**White-red-jack pine and spruce-fir.**—These forest ecosystems occur in the northeastern part of the Northern Section (numbers 10 and 11, fig. 5). Valued primarily

<sup>2</sup>The relationship between the Society of American Foresters' forest types and FRES is presented in Eyre (1980). More detailed forest and range classification have been developed for specific regions, e.g. for western forests: Alexander (1985), Barbour and Major (1977), Johnston (1987), Franklin and Dyrness (1973), Mauk and Henderson (1984), Pfister et al. (1977); and for the eastern forests: Braun (1964). FRES types were not defined for Alaska and Hawaii. Forest and rangelands in Alaska were described in McNicholas (1983). Hawaii ecosystems have been described by Stone and Scott (1987).

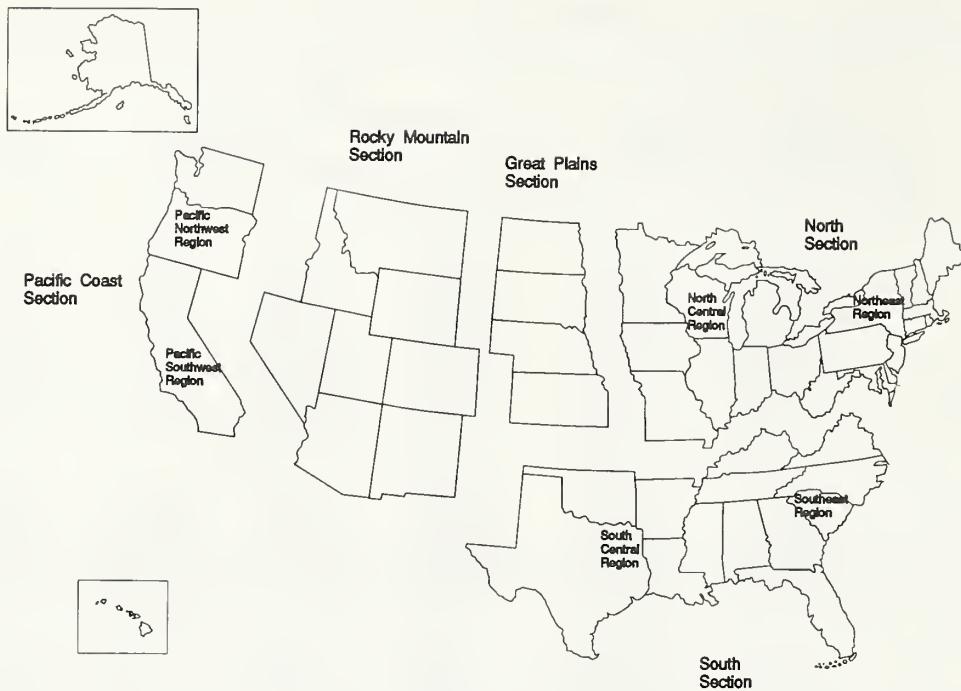


Figure 2.—Sections and regions of the United States.

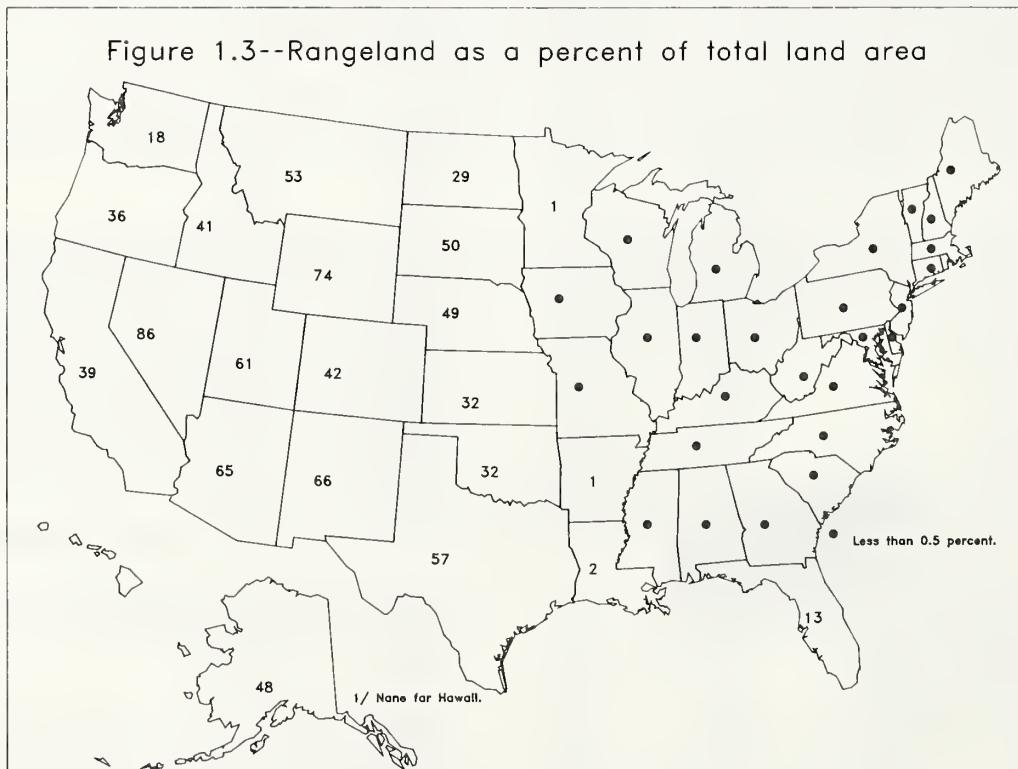


Figure 3.—Rangeland as a percent of total land area by State.

Figure 1.4--Forest land as a percent of total land area



Figure 4.—Forest land as a percent of total land area by State.



<sup>1</sup> Not mapped

Source: Garrison and others 1977

Figure 5.—Forest and range environmental system (FRES) ecosystems of the United States.

Table 2.—Forest and Range Environmental System (FRES) number and ecosystem name

FRES Number	Ecosystem	FRES Number	Ecosystem
10	White-red-jack pine	27	Redwood
11	Spruce-fir	28	Western hardwoods
12	Longleaf-slash pine	29	Sagebrush
13	Loblolly-shortleaf pine	30	Desert shrub
14	Oak-pine	31	Shinnery
15	Oak-hickory	32	Texas savanna
16	Oak-gum-cypress	33	Southwestern shrubsteppe
17	Elm-ash-cottonwood	34	Chaparral-mountain shrub
18	Maple-beech-birch	35	Pinyon-juniper
19	Aspen-birch	36	Mountain grasslands
20	Douglas-fir	37	Mountain meadows <sup>1</sup>
21	Ponderosa pine	38	Plains grasslands
22	Western white pine	39	Prairie
23	Fir-spruce	40	Desert grasslands
24	Hemlock-Sitka spruce	41	Wet grasslands
25	Larch	42	Annual grasslands
26	Lodgepole pine	44	Alpine

<sup>1</sup>Not mapped

Source: Garrison et al. 1977.

for their timber production, these ecosystems also contribute habitat to a variety of wildlife including white-tailed deer, moose, great horned owl, spruce grouse, and ruffed grouse (DeGraaf and Rudis 1986, Eyre 1980). The white-red-jack pine ecosystem also provides habitat for the endangered eastern timber wolf, peregrine falcon, and Kirtland warbler. Insects are important in the nutrient cycling and energy flow of the spruce-fir ecosystem. The spruce budworm, the eastern spruce beetle, and the black-headed budworm feed on needle leaves and, at epidemic levels, may cause serious damage to the forest stand (Shelford 1963). Understory vegetation is predominantly shrubs and forbs (Eyre 1980), and these types provide little forage for domestic livestock grazing.

**Maple-beech-birch and aspen-birch.**—These ecosystems commingle along the Canadian border of the Northern Section (numbers 18 and 19, fig. 5). Prior to European settlement, this area was covered with white-red-jack pine and spruce-fir ecosystems. Paper birch and aspen regenerate on sites disturbed by wildfire or human impact, and are usually succeeded by spruce-fir or pine types if left undisturbed, depending upon the location (Eyre 1980). The understory vegetation is typically shrubs or forbs providing good habitat for ruffed grouse, white-tailed deer, and moose (DeGraaf and Rudis 1986), while the cleared areas converted to pasture provide forage for the dairy industry of this region.

**Oak-pine and oak-hickory.**—These ecosystems span the central part of eastern United States, occurring in both the North and South Sections (numbers 14 and 15, fig. 5). Oak-pine forests are characterized by a stand composition of 50% or more in hardwoods and 25-49% in southern pines, mainly shortleaf pine. Grass and forb production is low in oak-pine when tree density is high (Thill and Wolters 1979), but can exceed a half ton per acre when the overstory is reduced by thinning (Wolters

et al. 1982). The oak-pine type provides habitat for game species such as white-tailed deer and wild turkey (DeGraaf and Rudis 1986). Six distinctive vegetation communities were defined in the oak-hickory type by Garrison et al. (1977). In three of these communities—the oak savanna, the mosaic of oak-hickory forest and bluestem prairie on the Ozark Plateau, and the cross timbers types—grasses and forbs contribute significantly to understory composition and production. Under proper management, forage production can exceed 2 tons per acre, providing valuable forage for beef livestock operations (Crawford and Porter 1974). The oak-hickory ecosystem provides habitat for game species such as white-tailed deer and mourning dove (Evans and Kirkman 1981), and a number of endangered plants and animals, including the southern bald eagle, red wolf, and the red-cockaded woodpecker.

**Loblolly-shortleaf pine.**—This forest ecosystem covers an extensive area in the northern part of the South Section (number 13, fig. 5). These forests are characterized by stands in which 50% or more of the stand is loblolly pine, shortleaf pine, or other southern yellow pines, singly or in combination. Much of the ecosystem has been converted to pine plantations, often mixed with pasture or row crops. Because of the large geographic extent of this type, the remaining stand composition is filled with many different kinds of trees associates. The characteristic understory vegetation is hardwoods, shrubs, woody vines, and pine regeneration. Changes in stand structure resulting from age and management alter the openness of the stand affecting forage production (Grenier 1978), species composition of birds (Hamilton and Yurkunas 1987, Whiting and Fleet 1987), and small mammal populations (Mullin and Williams 1987). Under an open canopy, pinehill bluestem contributes significantly to herbaceous production, and as the stand ages, longleaf uniola begins to dominate with a decline

in herbaceous production (Halls and Schuster 1965). This type is prime habitat for white-tailed deer (Thill 1983), wild turkey, bobwhite, and mourning dove.

**Longleaf-slash pine.**—This forest ecosystem rings the coastal edge of the South Section (number 12, fig. 5). A stand composition of 50% or more of longleaf and/or slash pine characterizes this ecosystem. Site and geographic location determine the remaining tree stand composition (Eyre 1980). Upland sites include flowering dogwood, other oaks, hickories, yaupon, persimmon, and hawthorn. Wetter sites may be associated with red maple, sweetgum, blackgum, water and laurel oak. Under periodic flooding, associates will include bald-cypress, pondcypress, blackgum, or water tupelo. Understory vegetation consists of grasses and/or shrubby vegetation. Understories in Louisiana, Mississippi, Alabama, and northwest Florida are dominated by blue-stem grasses (Grelen 1978). Florida and Georgia sandhills and pine flatwoods have an understory dominated by wiregrass with other species including saw-palmetto (Grelen 1978). Because of the extensive understory of grass, this type is an important ecosystem for domestic livestock grazing. A number of endangered plants and animals occur, including the red-cockaded woodpecker and the Florida panther. Bobwhite and wild turkey are important game birds. Intensive logging, land clearing with subsequent abandonment, fire suppression, and recent clearcutting and regeneration with either loblolly or slash pine have converted many longleaf-slash communities to pure stands of loblolly or slash pine (Eyre 1980, Grelen 1978).

**Oak-Gum-Cypress.**—This type is found in the Mississippi River flood plain and that of its tributaries as far north as Indiana, along other rivers in the South and Southeast, and in the mangrove swamps of Florida (number 16, fig. 5). Within the river flood plains, common tree associates are broad-leaved deciduous trees such as willow, maple, sycamore, cottonwood, and beech. The mangrove swamp provides habitat for white-tailed deer and for many endangered species such as the Florida manatee, brown pelican, bald eagle, hawksbill sea turtle, and Atlantic ridley sea turtle (Odum et al. 1982). The cypress savanna is dominated by needle-leaved deciduous trees and some broad-leaved evergreen or deciduous trees and shrubs. White-tailed deer commonly utilize these habitats, along with gray fox, gray squirrel, fox squirrel, and other small mammals. Wild turkey is an important game bird. The flooded areas provide habitat for ibises, cormorants, herons, egrets, and kingfishers. Endangered species include Bachman's warbler, Florida panther, and bald eagle. Much of this area has been converted to either cropland or pasture. In 1977, Garrison et al. (1977) estimated that only the wettest parts of this type remained in forest, about 10%.

**Elm-ash-cottonwood.**—This riparian vegetation type forms narrow corridors on the lower terraces and flood plains of the Mississippi, Missouri, Platte, Kansas, Arkansas, and Ohio Rivers (number 17, fig. 5). Low-to-tall broadleaved deciduous trees vary from open to dense stands. Common tree associates differ in the northern and southern extents. The cottonwood-willow stage is

usually succeeded by the Society of American Foresters type birch-maple-elm in the north and by sycamore-pecan-American elm or sugarberry-American elm-green ash in the south (Eyre 1980). This type is utilized by waterfowl and by other birds such as American woodcock and mourning dove (Evans and Kirkman 1981).

## Western Forest Ecosystems

**Douglas-fir.**—This forest ecosystem occurs in the Rocky Mountain and Pacific Coast Sections (number 20, fig. 5). Douglas-fir in the coastal regions occurs with western hemlock and western redcedar, and is not usually classified as a climax species because it is moderately intolerant to the low-light intensities characteristic of these forests. Within the Rocky Mountains, Douglas-fir tends to occur in pure stands (Mitchell 1983). Understory vegetation varies with the topographic, climatic, and edaphic conditions of the site and ranges from grass-dominated communities and sites densely vegetated with shrubs to sites with little understory vegetation (Mitchell 1983). Mature stands offer little browse or forage; however forest openings and early seral stages offer habitat for elk, deer, black bear, grizzly bear, moose, blue and ruffed grouse, hawks, owls, mammalian predators such as mountain lions and bobcats, and the endangered American peregrine falcon. The spotted owl, endangered in Oregon, has influenced the management of Douglas-fir lands in the Pacific Coast section (Salwasser 1987, Simberloff 1987). Fire suppression has favored tree regeneration at the expense of shrubs, grasses, and rapid tree growth (Arno and Gruell 1986, Gruell 1983, Wright and Bailey 1982). Under proper management, timber harvesting followed by slash burning opens up the site for range vegetation production, benefitting both wildlife and domestic livestock (Wright and Bailey 1982).

**Ponderosa pine.**—This forest ecosystem is also widely distributed in all western regions (number 21, fig. 5). By definition, the ponderosa pine ecosystem contains 50% or more of one of these pines: ponderosa, Jeffrey, sugar, limber, Arizona ponderosa, Apache, or Chihuahua (Garrison et al. 1977). The remaining stand composition varies by geographic region. Historical records indicate that fire kept this ecosystem open and park-like with an excellent ground cover of grasses, sedges, and forbs, or with an understory of shrubs (Wright and Bailey 1982). Black bear, mule deer, elk and mountain lion inhabit this forest type (Short 1983). This ecosystem provides timber, recreation, critical summer forage for livestock operations based at lower elevations, and prime habitat for mule deer and elk.

**Fir-spruce, hemlock-Sitka spruce, western white pine, and larch.**—These forest ecosystems occur in the Rocky Mountains along the northern boundary of the Pacific Coast and Rocky Mountain sections (numbers 22, 23, 24 and 25, fig. 5). Fir-spruce forests, which also occur further south in the Rocky Mountain Section, generally have a dense canopy with little understory vegetation, and provide little forage for domestic livestock. Shrubs or forbs

constitute the understory under the hemlock-Sitka spruce and the western white pine ecosystem and are also found under some fir-spruce types. Larch is a seral type, succeeding to grand fir or Douglas-fir (Eyre 1980). These ecosystems are interspersed with meadows or stream bottoms with broad-leaved woody species such as aspen and willows. This mosaic of ecosystems provides habitat for moose, elk, mule deer, and white-tailed deer (Clary 1983). Other mammals include wolverine, lynx, black bear, mountain lion, coyote, and in small numbers, the grizzly bear.

**Lodgepole pine.**—Widespread over the entire West, this ecosystem is characterized by a composition of 50% or more of lodgepole pine (number 26, fig. 5). Understory vegetation is a function of the climatic, topographic, and edaphic characteristics of the site, and the time since the last disturbance (Bartolome 1983). Logging and fire shift understory species composition toward grasses and forbs, reducing shrubs. The 25 million acres dominated by lodgepole pine provide a significant source of forage for wild and domestic animals (Bartolome 1983). The fauna is similar to the Douglas-fir and spruce-fir ecosystems.

**Redwood.**—This forest ecosystem covers a small geographic extent in California and Oregon (number 27, fig. 5). The dense overstory of redwood (20% or more) may be in association with Douglas-fir and grand fir. Fauna include elk, mountain lion, bobcat, and black bear.

**Western hardwoods.**—Occurring in the Pacific Coast and Rocky Mountain sections, these forests are characterized by a stand composition of 50% or more of coast live oak, canyon live oak, blue oak, valley oak, interior live oak, or aspen (number 28, fig. 5). Understory vegetation is primarily grasses. Fauna in the California extent include mule deer, California quail, mountain quail, skunk, and the endangered San Joaquin kit fox. Fauna in the Oregon extent is similar to the California extent, with the addition of more northerly species such as the ruffed grouse. In the Rocky Mountain extent, fauna is similar to the surrounding ecosystems. The aspen ecosystem in the Rocky Mountain section produces significant amounts of forage in addition to the valuable wood fiber (Betters 1983).

### Grassland and Shrubland Ecosystems

**Sagebrush.**—This ecosystem occupies the vast plains and plateaus derived from lava flows, ancient lake beds, and broad basins of alluvium in the Rocky Mountain and Pacific Coast Sections (number 29, fig. 5). Several different sagebrush communities are dominated by either different sagebrush species or by sagebrush and grass species (Blaisdell et al. 1982, West 1983a,b). In the early years of western settlement, this type was severely impacted through grazing, cultivation, and the later abandonment of marginal farms (Blaisdell et al. 1982). Disruption of the fire cycle in the sagebrush ecosystem has led to the encroachment and, in some cases, takeover of annual grasses, primarily cheatgrass (West 1983a,b). Heavy grazing pressure has reduced the occurrence of

the native perennial grasses, allowing sagebrush to increase in dominance. Annual exotic plants such as cheatgrass become established and provide the fine-textured fuel in the dry season that allows wildfires to spread from shrub to shrub (Young et al. 1987). The technology exists to reverse the process of annualization on sites with sufficient annual precipitation, however cheatgrass has expanded its range to include sites in the more arid margins of the Great Basin (Young et al. 1987). This ecosystem provides habitat for game species such as sage grouse, pronghorn, and mule deer (McArthur et al. 1987), and habitat for the endangered Utah prairie dog (Garrison et al. 1977). The invasion of cheatgrass has facilitated the successful introduction of the exotic game bird, chukar partridge, which uses cheatgrass as a staple item of its diet (Leopold et al. 1981). This ecosystem type supports the majority of wild horse and burro herds. (West 1983a, b).

**Desert shrub and southwestern shrubsteppe.**—These ecosystems are found in areas of the Rocky Mountain and Pacific Coast Sections (numbers 30 and 33, fig. 5) where precipitation is usually less than 10 inches a year, and the soils are poorly developed (Stoddart et al. 1975). Generally these types are referred to as cold-desert shrublands of the temperate latitudes and hot-desert shrublands of tropical and subtropical areas. The sparse vegetation is dominated by woody plants less than 7 feet in height. Shrub species in the cold desert include shadscale, saltbush, various rabbitbrushes, greasewood, and winterfat with associated grasses and minimal forb species. The exotic invader cheatgrass has adapted to produce seed in the brief period during spring when moisture is abundant. The cold-desert shrubland furnishes winter grazing for thousands of sheep and cattle (Stoddart et al. 1975) and habitat for wildlife species such as mule deer, pronghorn, coyote, and collared peccary (Short 1983). Feral horses use this ecosystem as well as sagebrush and annual grasslands ecosystems (McArthur et al. 1978, Verner and Boss 1980). The hot-desert shrublands of California, Arizona, New Mexico, and Texas are dominated by creosote bush, mesquite, blackbrush, bursage, tarbush, paloverde and cactus shrub. The dominant grass species of black grama, three-awns, and tobosa are associated with side-oats grama and curly mesquite. Desert mule deer, collared peccary, antelope, desert bighorn sheep, quail, dove, and rabbit are important game species (Martin 1975). The desert tortoise, endangered in California, Nevada and Arizona, also occurs here (Short 1983). Hot-desert shrublands are grazed yearlong by domestic livestock. This type represents the longest history (400 years) of grazing on this continent (Stoddart et al. 1975). The geographic region within which the ecosystems of southwestern shrubsteppe, desert shrub and desert grassland occur are drained by numerous rivers and streams. Riparian vegetation along these waterways has undergone severe manipulation from water developments, overgrazing, and invasion of exotics such as saltcedar (Swift 1984).

**Shinnery.**—This ecosystem forms a narrow corridor on the sand hills and river dunes along the Canadian River in Texas (number 31, fig. 5). This midgrass prairie

is associated with open to dense stands of broad-leaved deciduous shrubs, primarily shin oak, and occasionally needle-leaved low trees and shrubs. Grass species include little bluestem and side-oats grama, with occasional sand bluestem. Fauna reflect the surrounding ecosystems of plains grasslands, pinyon-juniper, and southwestern shrubsteppe ecosystems.

**Texas savanna.**—This high shrub savanna ecosystem varies from dense to open canopies of broad-leaved, deciduous and evergreen low trees and shrubs, and needle-leaved evergreen low trees and shrubs (number 32, fig. 5). The understory component is short-grass and mid-grass species, including bluestems, three-awns, buffalo grass, gramas, curly mesquite, and tobosa. Mesquite is the dominant shrub, although other shrubs include acacia, live oak, juniper, and ceniza shrub. This ecosystem is noted for the abundance of white-tailed deer, wild turkey (Garrison et al. 1977), and collared peccary (Schmidt and Gilbert 1978). Fox squirrel, ringtail, raccoon, mourning dove, scaled quail, and bobwhite also inhabit this ecosystem.

**Chaparral-mountain shrub.**—This ecosystem varies across the Pacific Coast and Rocky Mountain Sections within which it occurs (number 34, fig. 5). The California chaparral is characterized by little summer rainfall and comparatively heavy winter precipitation. While this ecosystem's chief value is watershed protection, some forage is also provided for livestock (Stoddart et al. 1975). Part of the critical habitat for the California condor, now found only in captivity, is within this type. Large portions of this ecosystem have been converted to annual grasslands. In the Rocky Mountain foothills, the scrub oak type occupies areas as open savannas or dense stands of oak. Found in scattered areas in Utah, Arizona, New Mexico, and Colorado, the mountain brush type occurs as a discontinuous transition zone between coniferous forest and grassland or sagebrush ecosystems (Stoddart et al. 1975). This type is not dominated by a single shrub species, but rather the shrubs of serviceberry, ceanothus, and snowberry form open stands under which grasses provide suitable forage for domestic livestock (Stoddart et al. 1975).

**Pinyon-juniper.**—This type, often adjacent to sagebrush, occupies the eroded and rough dissections of western basins and mountains in all of the western regions (number 35, fig. 5). Pinyon pine and juniper occur as dense to open woodland and savanna woodland. These tree species may grow to 30 feet tall, but commonly are under 15 feet. Understory vegetation appears to be related to climatic patterns in cold winter/dry summer regimes, cool season grasses are found; in dry winter climates, warm season grasses occur; and with moist cool winters, chapparal understories are associated with this type (Clary 1987). Livestock grazing has been an important use in this type where forage production may be as much as 600 pounds per acre in open stands (Clary 1987). Domestic livestock grazing is usually low-intensity, season-long or year-long (Clary 1987). While past heavy grazing and the increased tree overstory have reduced the forage production available within this type, prescribed fire can be

used to reestablish understory species (Everett 1987). Fauna include mule deer, mountain lion, coyote, bobcat, jackrabbit, and numerous species of birds. Commercial products from the pinyon-juniper woodlands are in greater demand today than 10 years ago (Spang 1987). The multiple use management of this ecosystem includes providing fuelwood, firewood, pine nuts, forage, wildlife habitat, watershed protection, recreational opportunities, esthetic values, wilderness, energy and mining activities (Spang 1987, Wagstaff 1987).

**Mountain grassland.**—Dominated by fescue and wheatgrass bunchgrasses, these grasslands are open untimbered areas surrounded by ponderosa pine, Douglas-fir, or lodgepole pine ecosystems (number 36, fig. 5). The encroachment of trees is slow because of several factors including strong competition for moisture from the bunchgrasses, low temperatures, and soil heaving. Fauna reflect the surrounding ecosystems. Grasslands at higher elevations in Colorado, Wyoming, and Montana were initially grazed 100 years ago and by 1900 most of these grassland were being grazed or were overgrazed. Current use is less than 25% of the former high levels (Paulsen 1975). These grasslands are still important summer ranges for cattle and wildlife, have significance as watersheds for water delivery downstream, and are important recreation areas. While considered originally part of the mountain grasslands (Garrison et al. 1977), the Palouse prairie is described as an intermountain-bunchgrass type by Stoddart et al. (1975). Unlike the mountain grasslands, the Palouse is a grassland not subject to invasion by trees. As a reflection of the deep soil high in organic matter, much of the Palouse Prairie in Oregon, Washington, and Idaho was plowed for production of small grains (Garrison et al. 1977).

**Mountain meadow.**—Wet to intermittently wet open sites within the forested zones in western mountains characterize this ecosystem (number 37, fig. 5). Grasses, sedges, and rushes dominate, and fauna reflect the surrounding ecosystems. This ecosystem serves as a source of water, yields highly productive forage for livestock and big game such as mule deer and elk (Turner and Paulsen 1976), and supports many recreational activities.

**Plains grassland.**—The short warm-season grasses of blue grama and buffalo grass dominate this ecosystem found in the Rocky Mountain Section (number 38, fig. 5). These grasses coexist with a minor component of forbs and shrubs, such as juniper, sagebrush, silver buffaloberry, skunkbush sumac, rabbitbrush, and mesquite. Two environmental gradients determine species composition within this type: the temperature gradient, which increases from north to south, and the moisture gradient, which increases from west to east (Stoddart et al. 1975). Pronghorn, mule deer, white-tailed deer, and white-tailed and black-tailed jackrabbit utilize this type. Prairie dogs and a variety of small rodents provide food for coyotes and raptors. The greater prairie chicken and sharp-tailed grouse are important game species. Grasshoppers annually consume about one-fifth of available range vegetation (Hewitt and Onsager 1983) and, at epidemic levels, can present

considerable damage to the forage base. The long-billed curlew was once widely distributed across this region, and its decline may be associated with decreasing short-grass prairie habitat (Kantrud 1982). The primary economic use of this ecosystem is domestic livestock grazing; however, the conversion of native grassland to agriculture, called sodbusting, reached high levels during the late 1970s when a poor livestock economy was coupled with a relatively good grain market (Heimlich 1985, Huszar and Young 1984). This extensive land conversion provided much of the incentive for conservation provisions in the 1985 Farm Bill (Joyce and Skold 1988). Within the plains grasslands and the prairie ecosystems, riparian communities such as elm-ash-cottonwood or oak-hickory ecosystems occur along major river systems. The relative lack of forest vegetation on the plains makes these riparian communities important to wildlife. Channelizations of streams and agricultural developments have significantly reduced the original area of the riparian ecosystems (Swift 1984).

**Prairie.**—This ecosystem is known as the true prairie (Risser et al. 1981). Bluestem grasses dominate and woody vegetation is rare. Some forbs occur. Fauna is similar to the plains grasslands ecosystem. The northern extent of this type, known as the prairie pothole region, is an important breeding ground for migratory waterfowl. Shelterbelt plantings have increased the habitat for birds such as mourning doves. Because of high soil fertility, much of this type has been converted to cropland. The eastern interface of this ecosystem with the eastern deciduous forests results in a mixing of grasses, shrubs and some trees in this type (number 39, fig. 5). Fire and goats have been used to suppress shrub and tree invasion into the prairie (Wright and Bailey 1982).

**Desert grassland.**—Blue and black grama, galleta, tobosa, curly mesquite, and several three-awn species vary with the moisture regime of a site (number 40, fig. 5). Shrubs, such as creosote bush, burroweed, cactus, and mesquite have been associated with this type, however, shrub invasion of grasslands has become a widespread phenomenon over the past 100 years (Pieper et al. 1983). Five factors are suggested for the invasion: increased livestock grazing, climatic change, increased competition among plant species, rabbits and rodents, and fire control. Pronghorn, collared peccary and mourning dove inhabit this ecosystem (Short 1983). Grasshoppers and harvester ants can cause considerable damage to desert grassland vegetation (Pieper et al. 1983).

**Wet grasslands.**—This diverse type occurs as the wet prairies and marshes along the eastern coast, the Florida Everglades and palmetto prairie, the tule marshes in central California, and the wet grasslands on the floodplains in the intermountain plateaus (number 41, fig. 5). Cordgrass, saltgrass and a few forbs form the coastal grassland ecosystem. Scattered shrubs and low to medium tall trees form the overstory with an understory of wiregrass and saw-palmetto in the palmetto grassland, or sawgrass and three-awn in the Everglades. Tules, other bulrushes, and sedges dominate the landscape in

the wet marshes in the intermountain floodplains. Fauna in wet grasslands are as diverse as the grasslands. The Central Valley of California and the coastal marshes of Texas and Louisiana are important habitat for seasonal migrations of waterfowl, including the whooping crane. Klopatek and others (1979) estimated that by 1974 tule marshes had lost 89% of their original area, the Everglades had been reduced 57%, and the palmetto prairie had been reduced 27%. Losses were primarily to agriculture.

**Annual grasslands.**—Introduced annual grasses dominate the vegetation, although forbs and perennial bunchgrasses can also be found. Fauna includes mule deer, California quail, and numerous small mammals. The mourning dove is also an important species here (Verner and Boss 1980). Much of this type at lower elevations has been converted to irrigated agricultural land (number 42, fig. 5). At higher elevations, use is mainly livestock grazing, some dry farming, and intensive recreational use in proximity to large metropolitan areas in California (California Department of Forestry 1987).

**Alpine.**—This type occurs above timberline in the Rocky Mountain and Pacific Coast Sections (number 44, fig. 5). Grasses, grasslike species, and forbs predominate. The particular composition reflects the environment of the site which can vary dramatically depending upon wind and water stress, from wind swept, highly erosive, dry slopes to wet meadows. Lakes and ponds with endemic trout can be found within the type, although many lakes have been stocked with introduced species. Year-round mammals include the pika, pocket gopher, and the yellow-bellied marmot. An important game bird is the ptarmigan. Mule deer, elk, and mountain sheep use the ecosystem for summer forage. Traditionally, large bands of domestic sheep have grazed this ecosystem in summer. This practice has diminished, however, consistent with the decline in per capita consumption of lamb and mutton. Recreational use consists of hiking, hunting, and fishing during the summer, and skiing during the winter (Thilenius 1975).

## OWNERSHIP

Most of the Nation's forest and rangelands are in non-federal ownership. In 1987, about 1 billion acres, 67% of the total were owned by nonfederal public agencies, forest industry, farmers and ranchers, and other private individuals (table 3). Federal lands are administered primarily by two agencies: the Forest Service, responsible for 182 million acres of National Forest System lands; and the Bureau of Land Management, responsible for 176 million acres of National Resource Lands. The remaining federal lands are administered primarily by the National Park Service, the Fish and Wildlife Service in the Department of Interior, and the Department of Defense.

The nonfederal forest lands are concentrated in the East, and private rangelands are concentrated in the West (table 3 and fig. 6). In the North and Great Plains there are 78 million acres of rangeland, most of which is in

Table 3.—Ownership of forest and rangeland areas (thousand acres) in the United States by section and region, 1987

Section and region	Total forest and rangeland						Forest land <sup>1</sup>						Rangeland					
	Federal lands administered by			Federal lands administered by			Federal lands administered by			Federal lands administered by			Federal lands administered by			Federal lands administered by		
	Total	Forest	Bureau of Land Mgt.	Other	Non-Federal	Federal	Total	Forest	Bureau of Land Mgt.	Other	Non-Federal	Federal	Total	Forest Service	Bureau of Land Mgt.	Other	Non-Federal	
North	85,269	2,499	—	755	82,015	85,253	2,499	—	755	81,999	16	—	—	—	—	—	16	
Northeast	80,630	8,578	88	1,201	70,763	80,220	8,513	88	1,094	70,525	410	65	—	—	107	107	238	
North Central	11,077	88	1,956	152,778	165,473	11,012	88	1,849	152,524	426	65	—	—	107	107	254		
Total	165,899	11,077	88	1,956	152,778	165,473	11,012	88	1,849	152,524	426	65	—	—	107	107	254	
South	92,133	5,266	—	4,140	82,727	87,744	5,266	—	3,943	78,535	4,389	—	—	—	197	197	4,192	
Southeast	227,106	7,189	11	2,733	217,173	215,741	7,189	11	2,734	105,808	111,385	—	—	—	—	—	—	111,365
South Central	319,239	12,455	11	6,873	299,990	203,485	12,455	11	6,676	184,343	115,754	—	—	—	197	197	115,557	
Rocky Mountains and Great Plains	473,922	95,539	142,490	23,851	212,042	138,104	68,306	19,196	6,967	43,635	335,818	27,233	123,294	16,884	168,407	168,407		
Rocky Mountains	81,807	3,560	323	717	77,207	4,227	1,008	—	92	3,127	77,580	2,552	323	625	625	625	74,080	
Great Plains	555,729	99,099	142,813	24,568	289,249	142,331	69,314	19,196	7,059	46,762	413,398	29,785	123,617	17,509	242,487	242,487		
Pacific Coast	381,244	36,363	22,765	89,751	232,365	178,956	31,413	5,524	26,553	115,466	202,288	4,950	17,241	63,198	116,899	116,899		
Pacific Northwest	79,616	23,429	10,129	7,401	38,657	41,129	17,566	2,172	1,482	19,909	38,487	5,863	7,957	5,919	5,919	5,919	18,748	
Pacific Southwest	460,860	59,792	32,894	97,152	271,022	220,085	48,979	7,696	28,035	135,375	240,775	10,813	25,198	69,117	69,117	69,117	135,647	
Total	1,501,727	182,423	175,806	130,549	1,012,949	731,374	141,760	26,991	43,619	519,004	770,353	40,663	148,815	86,930	493,945	493,945		
United States Total																		

<sup>1</sup>See footnote 1, table 1.

<sup>2</sup>Data reported in this table might differ from data reported in summary assessment document. Rangeland area data for the summary document have been reconciled with the Soil Conservation Service. Forest land area reported in this table has not been reconciled.

Note: Data may not add to totals because of rounding.

Source: Forest Service RPA data base, 1987 and Soil Conservation Service reconciled figures, 1982.

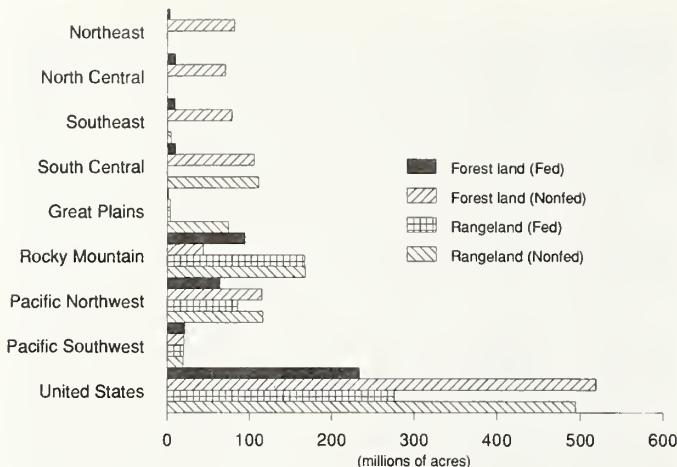


Figure 6.—Ownership of forest and rangeland by geographic region, 1987.

the Great Plains. Ninety-five percent of this rangeland is in nonfederal ownership. Nearly 156 million acres, or 92% of the forest land total in these 2 sections, is under nonfederal ownership. In the two southern regions, over 99.8% of the 116 million acres of rangeland is in nonfederal ownership and is located in Texas, Oklahoma, and Florida. Ninety percent of the 200 million acre total of forest land is in nonfederal ownership.

The three western regions, which include Alaska and Hawaii, have a forest and rangeland base of 935 million acres. About 38% is forested. The ownership of the western forests (358 million acres) is evenly divided between the federal government and other public and private owners, as is ownership of the 577 million acres of western rangelands.

The Rocky Mountain Section accounts for the largest area of rangeland in the United States (44% of the total), under both federal and nonfederal ownerships. The Section also accounts for a greater amount of federal forest land acres than any other Section. The largest area of nonfederal forest land is located in the South.

## FOREST LAND PRODUCTIVITY

For this assessment, productivity of forest land is defined as the amount of wood per acre per year that can be produced in fully stocked natural stands. The natural potential has been used because measures of the potential are available for most regions of the United States, and it provides a uniform means of describing productivity of forests.

While no single measurement adequately describes the productivity of forest land for uses other than timber, an estimate of biological productivity is sometimes useful in helping to determine the forest's relative capacity for other uses. Chief among the factors that influence productivity for timber are soil, climate, and topography.

Major forest ecosystems will probably not be cleared for herbage and browse production, even though their

potential productivity for forage is high. Such forest land types as the open-grown pine lands in the western United States currently produce considerable forage for domestic livestock and herbage and browse for deer and other wildlife. Under proper management, these types could probably produce increased quantities of forage; however, such management might lead to a reduction in the level of timber production.

Most of the Nation's high productivity forest lands are located west of the Cascade Mountains in the Pacific Northwest Region and in the South Central Region. Nearly 16 million forest land acres in the Pacific Northwest Region and about 21 million acres in the South Central Region have the potential for producing wood at a rate exceeding 120 cubic feet per acre per year in natural timber stands (table 4). The Pacific Northwest Region has the greatest area of low productivity lands; mainly because interior Alaska is included in the Region. Some 105 million acres, which represent 87% of Alaska's unreserved forest land total, has the potential of producing less than 20 cubic feet per acre per year. The Rocky Mountain Region also has large areas of low productivity forest. Over half of the forest land has the potential for producing less than 20 cubic feet per acre per year, and over three quarters of it can produce less than 50 cubic feet.

In the West, 77% of the redwood ecosystem of 1.3 million acres is highly productive (table 5). However, the largest areas in the 120 + cubic feet class are in the coastal Douglas-fir and hemlock-Sitka spruce types. High elevation fir-spruce, western hardwood, and arid land pinyon-juniper ecosystems are low in potential productivity. Fifty million acres of pinyon-juniper in the western interior and 68 million acres of fir-spruce make up nearly three-fifths of all of the forest land whose potential productivity is less than 20 cubic feet per acre per year. High elevation fir-spruce accounts for 34% of all forest lands in the lowest productivity class.

In the East, highly productive sites are found in the loblolly-shortleaf pine and oak-gum-cypress ecosystems of the lower Mississippi drainage and Atlantic coastal plain. Although no individual type can be identified with low-productivity sites, high-elevation fir-spruce accounts for 27% of the total forest land whose potential productivity is rated at less than 20 cubic feet per acre per year.

## RANGELAND CONDITION

The term range condition has traditionally been used as a measure of the health of the range ecosystem. The Forest Service, SCS and BLM use different measures of range condition to inventory the Nation's rangelands. The Soil Conservation Service (SCS) inventories non-federal rangelands and defines range condition as "...The present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant

Table 4.—Forest land area (million acres) in the United States, by timber productivity class, section and region, 1987

Section and region	Total	Productivity class <sup>1</sup>				
		120 + cu.ft.	85-120 cu.ft.	50-85 cu.ft.	20-50 cu.ft.	0-20 cu.ft.
North						
Northeast	85.3	3.5	15.3	37.3	26.5	2.7
North Central	80.2	3.5	15.0	29.3	29.5	2.9
Total	165.5	7.0	30.3	66.6	56.0	5.6
South						
Southeast	87.7	3.5	21.4	49.4	12.3	1.1
South Central	115.7	21.2	37.6	38.7	13.5	4.7
Total	203.4	24.7	59.0	88.1	25.8	5.8
Rocky Mountains and Great Plains						
Rocky Mountains	138.1	3.4	9.3	20.9	31.9	72.6
Great Plains	4.2	—	.3	1.0	2.3	.6
Total	142.3	3.4	9.6	21.9	34.2	73.2
Pacific Coast						
Pacific Northwest	179.0	15.9	11.3	12.3	19.3	120.2
Pacific Southwest	41.1	6.3	4.5	5.7	3.4	21.2
Total	220.1	22.2	15.8	18.0	22.7	141.4
United States Total	731.4	57.3	114.7	194.6	138.7	226.1

<sup>1</sup>A measure of the mean annual growth obtainable in cubic feet per acre in fully stocked natural stands.  
Source: Forest Service RPA data base, 1987.

Table 5.—Forest land area (million acres) in the United States, by timber productivity class and ecosystem, 1987

Ecosystem	Total	Productivity class <sup>1</sup>					Reserved forest land
		120 + cu.ft.	85-120 cu.ft.	50-85 cu.ft.	20-50 cu.ft.	0-20 cu.ft.	
Forest land							
Eastern forest							
White-red-jack pine	14.5	1.3	2.5	5.5	4.5	0.2	0.5
Fir-spruce	19.6	.5	2.3	6.8	7.2	2.1	.7
Longleaf-slash pine	15.8	.8	3.7	8.5	2.4	.1	.3
Loblolly-shortleaf pine	49.1	8.2	17.0	19.2	4.1	.1	.5
Oak-pine	31.6	4.6	9.3	13.0	4.3	.2	.2
Oak-hickory	1250.4	7.4	27.2	52.0	30.5	5.4	2.5
Oak-gum-cypress	29.5	4.4	9.0	11.7	2.7	1.0	.7
Elm-ash-cottonwood	15.1	1.3	3.1	5.1	4.7	.6	0.3
Maple-beech-birch	47.9	2.0	8.2	19.4	13.6	1.1	3.6
Aspen-birch	18.6	0.3	4.6	8.4	4.2	.3	.8
Nonstocked	6.5	( <sup>2</sup> )	.3	2.0	3.1	1.0	.1
Total	373.2	30.8	87.2	151.6	81.3	12.1	10.2
Western forest							
Douglas-fir	41.1	9.0	7.5	9.1	6.7	2.8	6.0
Ponderosa pine	30.6	1.4	1.9	6.0	15.3	3.0	3.0
Western white pine	.3	.1	.2	( <sup>2</sup> )	( <sup>2</sup> )	( <sup>2</sup> )	( <sup>2</sup> )
Fir-spruce	103.5	2.6	4.1	10.3	9.9	68.2	8.4
Hemlock-Sitka spruce	19.1	4.0	4.0	1.8	1.2	5.5	2.6
Larch	2.7	.5	1.2	.8	.1	( <sup>2</sup> )	.1
Lodgepole pine	18.2	.2	1.2	3.5	6.6	2.7	4.0
Redwood	1.3	1.0	.1	( <sup>2</sup> )	—	( <sup>2</sup> )	.2
Other western softwoods	27.2	.1	.1	.2	0.4	22.0	4.4
Western hardwoods	48.9	3.9	1.7	2.6	7.6	29.4	3.7
Nonstocked	5.4	.5	.3	.5	1.1	2.5	.5
Total	289.3	23.3	22.3	34.8	48.9	136.1	32.9
Other forest							
Chaparral	8.1	—	—	—	—	7.3	.8
Pinyon-juniper	51.8	—	—	—	—	50.0	1.8
Total	59.9	—	—	—	—	57.3	2.6
United States total	731.4	54.1	109.5	186.4	130.2	205.5	45.7

<sup>1</sup>A measure of the mean annual growth obtainable in cubic feet per acre in fully stocked natural stands.

<sup>2</sup>Less than 100,000 acres.

Source: Forest Service RPA data base, 1987.

Table 6.—Condition<sup>1</sup> of nonfederal rangeland area (thousand acres) by section and state, 1982

Section and state	Condition Class					
	Total	Excellent	Good	Fair	Poor	Other
North						
Minnesota	198.5	20.4	47.8	100.3	27.6	2.4
Missouri	217.8	1.3	56.2	99.7	55.6	5.0
Total	416.3	21.7	104.0	200.0	83.2	7.4
South						
Arkansas	164.6	4.9	21.5	70.2	68.0	0.0
Florida	3,803.9	24.5	272.5	1,831.4	1,640.1	35.4
Louisiana	241.3	12.5	148.5	54.0	26.3	0.0
Oklahoma	15,059.6	906.8	3,601.6	7,638.6	2,903.9	8.7
Texas	95,353.0	479.9	13,546.3	53,542.8	25,680.5	2,103.5
Total	114,622.4	1,428.6	17,590.4	63,137.0	30,318.8	2,147.6
Rocky Mountains and Great Plains						
Arizona	30,948.2	517.7	4,923.6	16,574.1	8,831.9	100.9
Colorado	24,222.5	333.2	5,802.6	14,012.2	4,033.2	41.3
Idaho	6,732.9	322.6	2,187.3	2,565.9	1,255.3	401.8
Kansas	16,908.9	965.5	8,091.9	6,121.9	1,666.2	63.4
Montana	37,837.0	5,027.5	17,272.1	12,605.1	2,747.2	185.1
Nebraska	23,095.7	2,188.5	12,636.1	7,110.2	1,069.0	91.9
Nevada	7,907.8	239.2	2,674.4	4,027.0	658.8	308.4
New Mexico	40,981.9	658.7	12,262.5	22,617.4	5,421.5	21.8
North Dakota	10,908.4	1,524.2	6,295.3	2,760.7	328.2	0.0
South Dakota	22,783.6	1,876.7	13,715.9	6,486.0	704.0	1.0
Utah	8,489.3	154.9	1,724.5	4,027.0	2,451.3	131.6
Wyoming	26,915.1	331.0	11,609.6	13,988.1	976.4	10.0
Total	257,731.3	14,139.7	99,195.8	112,895.6	30,143.0	1,357.2
Pacific Coast						
California	18,124.6	29.3	472.9	613.2	434.0	16,575.2
Oregon	9,392.0	226.4	1,813.2	3,485.5	3,731.1	135.8
Washington	5,637.0	629.0	1,168.5	1,816.1	1,933.0	0.4
Total	33,153.6	884.7	3,454.6	5,914.8	6,098.1	16,801.4
United States Total	405,913.6	16,474.7	120,344.8	182,097.4	66,683.1	20,313.6

<sup>1</sup>SCS defines range condition as: "...the present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site."

Source: Table 41a.—Pasture land condition in 1982 by land compatibility subclass. Basic Statistics, 1982 National Resources Inventory, Soil Conservation Service, Iowa State University Statistical Laboratory, Statistical Bulletin No. 756, p. 64.

community for the site" (USDA Soil Conservation Service 1987). Montana leads all other states in area of non-federal rangeland in the excellent condition class according to SCS estimates with 5.0 million acres (table 6). Nebraska is next (2.2 million acres), followed by South Dakota (1.9 million acres). States in the arid West contain the largest areas of rangeland in the poor condition class: Texas (25.7 million), Arizona (8.8 million) and New Mexico (5.4 million).

The Bureau of Land Management and the Forest Service have adopted separate ratings for ecological status and resource value rating. Both agencies are in a transition stage in inventory, monitoring and reporting. The Bureau of Land Management used data from a combination of ecological site inventory, soil vegetation inventory method and professional judgement. Rangeland administered by the Bureau of Land Management (BLM) with the greatest area in the excellent condition class

is found in Nevada (2.8 million acres), followed by Utah (1.0 million) and Wyoming (0.8 million) (table 7). Arizona, with 26.0 million acres, leads BLM rangeland in the poor condition class, followed by Nevada (10.8 million) and New Mexico (3.0 million).

The Forest Service reported rangeland condition in 1987 in terms of ecological status and satisfactory livestock forage conditions. Seventy-nine percent of the rangeland on the national forests is classed as satisfactory, and 21% is classed as unsatisfactory (table 8).

## WATER AREAS

About 5% of the total area of the United States is water (table 1). This water area includes ponds, lakes, and reservoirs that are at least 2 acres in size and streams and waterways that are at least 120 feet wide. It also includes

Table 7.—Condition of BLM rangeland area (thousand acres) by section and state, 1986

Section and state	Condition Class					
	Total	Excellent	Good	Fair	Poor	Other
<b>Rocky Mountains</b>						
Arizona	36,006	427	3,006	6,587	25,986	—
Colorado	7,197	222	1,179	3,089	1,992	715
Idaho	12,108	415	2,730	3,724	2,717	2,522
Montana	8,221	397	4,924	1,886	109	905
Nevada	45,121	2,759	12,059	18,372	10,819	1,112
New Mexico	12,889	57	3,131	6,142	2,977	582
Utah	20,845	965	6,895	9,023	297	3,665
Wyoming	17,668	836	8,035	6,414	1,097	1,286
Total	160,055	6,078	41,959	55,237	45,994	10,787
<b>Pacific Coast</b>						
California	9,179	69	4,011	3,992	952	155
Oregon	13,922	537	3,528	7,027	2,363	467
Total	23,101	606	7,539	11,019	3,315	622
All Sections Total	183,156	6,684	49,498	66,256	49,309	11,409

Source: Combination of ecological site inventories, soil vegetation inventories, and professional judgment.

coastal waterways, major coastal bays and harbors, except those in Alaska and Hawaii, and the Great Lakes.

Of the 108 million acres of water, 51 million acres is in large lakes and streams that are 40 acres or larger (but not the Great Lakes). Fifty-four percent of these large lakes and streams (27 million acres) are located in the eastern half of the country. Within the East, the large water areas are concentrated in the northernmost tier of states, where glaciation formed numerous lake basins; and in the southernmost tier of states, where part of the low-lying land along the coasts and major rivers is covered with water. The remaining 24 million acres in the western states are contained in manmade reservoirs and impoundments constructed to store water for irrigation, electric power generation, and flood control.

The area of small inland water, which includes streams that are less than one-eighth mile in width and lakes and ponds between 2 and 40 acres in size, amounts to 9.9 million acres. Many of these small water areas are manmade, largely the product of federal and state programs concerned with watershed protection, flood control, or wildlife value enhancement. The geographic distribution of these small water areas is similar to that of the large water areas, generally tied to landform and rainfall.

About 36 million of the 46 million acres of coastal waterways, harbors, and bays are the in Great Lakes. The largest bays include Chesapeake, Delaware, and San Francisco; large harbors include New York; largest sounds include Long Island and Puget; and largest straits include Juan de Fuca and Georgia. These and the other coastal water bodies along the Atlantic, Gulf, and Pacific Coasts are included in the total water figure for the United States. These navigable waters are considered to be publicly owned and, therefore, are regulated by federal and state laws. In many cases, however, public access is controlled by the owners of the adjoining lands.

## ENVIRONMENTAL HEALTH

### Atmospheric Deposition

The forests, grasslands, and croplands of the United States supported a population of 1-2 million native Americans when European colonization began in the 16th and 17th centuries. Today, the U.S. land base supports the food, fiber, outdoor recreation, and environmental needs of about 240 million people. Additionally, the U.S. in the last decade exported 40% of the value of its cropland, 5% of its livestock production, and 17% of the industrial wood harvest (Council on Environmental Quality 1985). Increasingly, the land base must not only support more people but also accept the wastes and byproducts of our industrialized society.

During the last 5-10 years, concerns have increased about the possible effects of airborne pollution on forests. Interest has been generated, in part, by the importance and continued concern about acidic precipitation ("acid rain") and forest declines. The current, severe forest deterioration in central Europe has also aroused concern for North American forests. At this time there are still insufficient data to conclude that these recent changes in forest condition constitute a new type of forest decline in the United States.

### Sources and Types

Atmospheric deposition or "acid rain" is not a new phenomenon. A study of the chemistry of precipitation around the town of Manchester completed in 1852 by an English chemist named Robert Smith was one of the first reports of strong acid occurrence in precipitation. Primary pollutants, directly emitted into the atmosphere as gases, include sulfur dioxide ( $SO_2$ ), nitrogen oxides

Table 8.—Condition of national forest rangeland suitable acres<sup>1</sup> (thousand acres) by section and state, 1987

Section and state	Ecological status											
	Total		Potential natural communities		Late serial		Mid-serial		Early Serial		Annual grasslands	
	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
<b>South</b>												
Alabama	56	—	( <sup>2</sup> )	—	37	—	3	—	16	—	—	—
Arkansas	691	38	214	11	337	18	120	7	20	2	—	—
Florida	133	—	8	—	101	—	24	—	—	—	—	—
Georgia	63	42	—	—	62	41	—	—	1	1	—	—
Kentucky	4	—	—	—	( <sup>2</sup> )	—	—	—	( <sup>2</sup> )	—	—	—
Louisiana	188	—	—	—	179	—	—	—	9	—	—	—
Mississippi	69	37	—	—	5	19	59	18	5	—	—	—
Oklahoma	242	11	77	4	133	5	28	1	4	1	—	—
Texas	631	4	190	—	91	—	103	—	247	4	—	—
Virginia	7	—	—	—	3	—	2	—	2	—	—	—
<b>Total</b>	<b>2,080</b>	<b>132</b>	<b>489</b>	<b>15</b>	<b>948</b>	<b>83</b>	<b>339</b>	<b>26</b>	<b>304</b>	<b>8</b>	<b>—</b>	<b>—</b>
<b>Rocky Mountains and Great Plains</b>												
Arizona	6,286	2,437	1,526	40	2,863	367	1,654	1,336	243	694	—	—
Colorado	4,297	614	162	13	984	59	2,594	261	557	281	—	—
Idaho	3,901	935	748	11	1,886	23	1,045	604	222	297	—	—
Kansas	34	71	—	—	8	—	26	33	—	38	—	—
Montana	2,287	222	804	93	835	65	455	44	193	20	—	—
Nebraska	295	41	6	—	34	—	209	31	46	10	—	—
Nevada	1,280	1,025	218	( <sup>2</sup> )	516	( <sup>2</sup> )	503	323	43	702	—	—
New Mexico	4,279	1,523	926	44	1,407	205	1,719	982	227	292	—	—
North Dakota	910	19	414	9	356	7	123	3	17	( <sup>2</sup> )	—	—
South Dakota	1,001	295	75	1	536	2	381	159	9	133	—	—
Utah	2,347	914	231	—	1,036	—	1,002	474	78	440	—	—
Wyoming	2,268	441	359	25	1,000	27	893	216	16	173	—	—
<b>Total</b>	<b>29,185</b>	<b>8,537</b>	<b>5,469</b>	<b>236</b>	<b>11,461</b>	<b>755</b>	<b>10,604</b>	<b>4,466</b>	<b>1,651</b>	<b>3,080</b>	<b>—</b>	<b>—</b>
<b>Pacific Coast</b>												
California	3,646	876	520	18	768	62	1,248	398	723	380	387	18
Oregon	4,885	863	683	45	1,776	154	1,814	350	612	314	—	—
Washington	926	170	78	10	135	24	366	52	347	84	—	—
<b>Total</b>	<b>9,457</b>	<b>1,909</b>	<b>1,281</b>	<b>73</b>	<b>2,679</b>	<b>240</b>	<b>3,428</b>	<b>800</b>	<b>1,682</b>	<b>778</b>	<b>387</b>	<b>18</b>
<b>United States total</b>	<b>40,722</b>	<b>10,578</b>	<b>7,239</b>	<b>324</b>	<b>15,088</b>	<b>1,078</b>	<b>14,371</b>	<b>5,292</b>	<b>3,637</b>	<b>3,866</b>	<b>387</b>	<b>18</b>

<sup>1</sup>The following terms are defined in USDA-Forest Service manual 2200:

**Ecological Status**—the degree of similarity between the present community and the potential natural community of a site. Ecological status considers only secondary succession.

**Suitable acres**—Acres within grazing allotments considered suitable for livestock grazing, i.e., that is accessible or that can become accessible to livestock, sustained-yield basis under reasonable management goals. Both rangelands and forested ranges are included in this table. There is overlap in acres in this table and acres described as forest land elsewhere in this chapter.

**Satisfactory livestock forage condition**—the soil is adequately protected and the forage species composition and production are at acceptable levels or the trend in forage species composition and production is acceptable.

<sup>2</sup>Less than 500 acres.

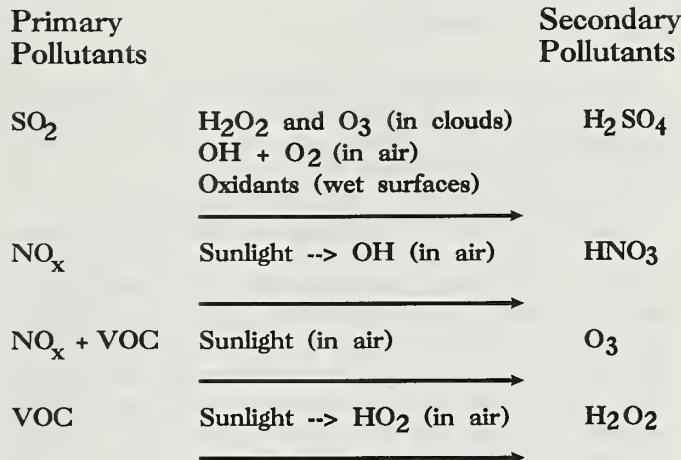
Source: U.S. Department of Agriculture, Forest Service, 1987. (Unpublished data), Range Management Staff, Washington DC.

(NO<sub>x</sub>), toxic trace metals, and volatile organic hydrocarbons (VOCs). Secondary pollutants are formed in the atmosphere during chemical reactions involving the primary pollutants. The most common of these are the acidic compounds formed when sulfur or nitrogen oxides combine with oxygen to form acidic gases or particles (dry deposition) or then combine with moisture to form acidic rain, snow, hail, sleet or fog (wet deposition) (fig. 7). Another secondary pollutant, ozone, is produced when sunlight triggers reactions involving NO<sub>x</sub>, oxygen, and VOCs. Ozone is very toxic to both humans and plants.

The burning of fossil fuels (coal, oil, natural gas) produces most of these pollutants. Natural sources of NO<sub>x</sub> and SO<sub>2</sub> provide 13% and 6%, respectively, of the annual emissions of these compounds, and include emissions from soils, oceans, agricultural crops, and natural vegetation (trees, shrubs, grasses) (Barchet 1987).

## U.S. Distribution

A high-quality weekly wet deposition network, the National Atmospheric Deposition Program's National



Source: NAPAP, 1987

Figure 7.—Acid rain—precursors and products.

Trends Network (NADP NTN), has been established across the United States. The Forest Service cooperates in this effort by supporting data collection at 11 sites on national forest land. The NADP NTN data, integrated with data from other wet deposition networks, provide a picture of the geographical distribution of the precipitation chemistry and wet deposition of a range of chemical species across the contiguous 48 states (fig. 8).

The area of highest acidity in rainfall for 1980-1985 is centered in western Pennsylvania, eastern Ohio, and Southwestern New York. Except for the West Coast, from Washington to California, where much of the annual precipitation falls as winter rains, wet deposition of most pollutants is higher in summer than in winter. The natural background (pre-1500 A.D.) pH of rain in the eastern U.S. may have been as low as 5.0. This is based on estimates of background concentrations of gaseous pollutants and on wet deposition measurements at remote areas of the earth today. In the semi-arid West, alkaline dusts raised by the wind could have neutralized some of the acidity and produced rain with slightly higher background pH (between 5.3 and 6.0) (Barchet 1987).

### Forest Declines

Declines from many causes (both known and unknown) have occurred periodically in tree species in the United States during the last 100-200 years. But in the last 10-20 years, forest condition changes have occurred in several forest regions that may be different from changes observed previously. Death rates of high elevation red spruce along the Appalachian Mountain chain in the northeastern U.S. appear to have increased (fig. 9), and numbers of standing dead spruce are higher than expected. This is not the case with northeastern,

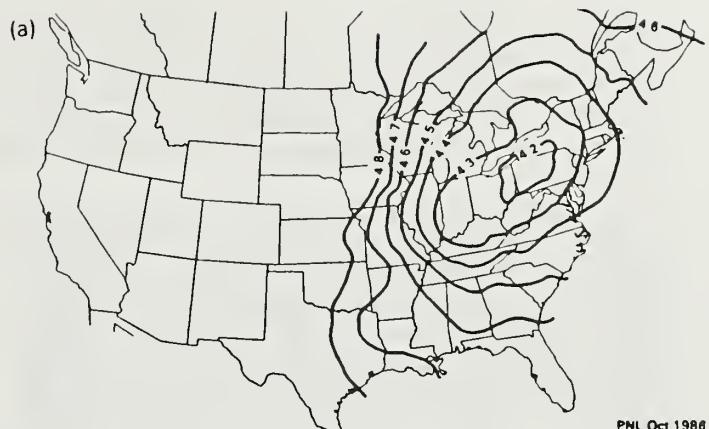
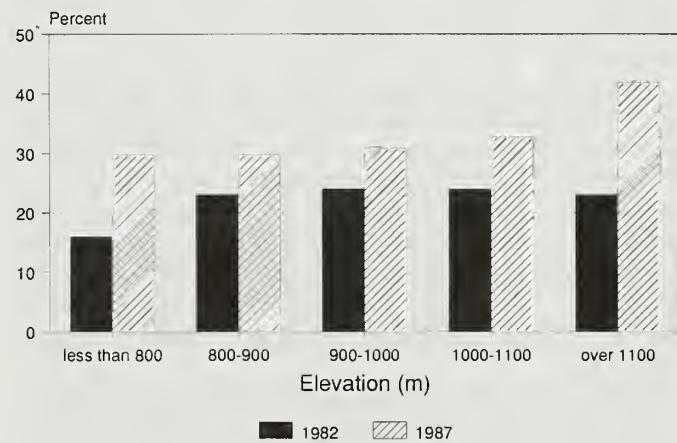


Figure 8.—The 1980-1984 annual composite distribution of (a) precipitation-weighted pH.



SOURCE: FS/EPA Forest Response Program.

Figure 9.—Percent standing dead spruce in northeastern United States selected survey plots, 1982-1987.

low elevation red spruce and southeastern, high elevation red spruce. Radial increment growth decreases (starting about 1960) have been documented at high and low elevations. These growth reductions have been consistent, abrupt, and unreversed. Death rates and growth of northern, high-elevation fir forests are unchanged. Growth decreases have occurred (since 1970) for northern, low-elevation balsam fir.

Radial growth decreases have also been reported in natural stands of commercially important conifer species (loblolly pine, slash pine) in the Southeast and shortleaf pine in the East at low elevations, with no visible foliar symptoms. Visible foliar damage and growth decreases have been documented for eastern white pine, and for ponderosa pine, Jeffrey pine, white fir, limber pine, incense cedar, and California black oak in southern and central California. Sugar maple decline has recently been reported in the northeastern U.S. and southeastern

Canadian provinces; the most severe damage occurs in stands managed for maple syrup production. Symptoms include branch and top dieback, decrease in sap production, and increased mortality. For most of these recent forest condition changes, the cause is still unknown.

Airborne pollutants are among the suspected causes of death in high elevation spruce, of spruce growth decreases, and of eastern and southeastern pine growth decreases. Recent results of atmospheric monitoring show that high-elevation forests are being exposed to greater pollutant concentrations and/or deposition than low-elevation forests in the East. Other recent results from dendrochronology (tree-ring) studies indicate that natural forest stand aging may account for the radial growth declines observed in low elevation spruce and fir forests. Damage to southern Fraser fir forests is being caused by the balsam woolly adelgid. Acidic deposition and management intensity are speculated factors in the apparent sugar maple decline in North America. A cooperative U.S.-Canadian study is investigating this decline.

The airborne pollutant ozone has been shown to cause visible foliar injury, decreased growth, and change in the species composition of some forests in southern California. Death of trees weakened by ozone is usually caused by secondary agents such as bark beetles and root-rotting fungi. The foliar injury symptoms have been duplicated experimentally in controlled exposure tests with ozone. Ozone has also been shown to induce visible injury and decrease growth in eastern white pine.

In all cases, airborne pollutants cannot yet be ruled out as one of the stresses causing these forest condition changes. Indeed, it is possible that air pollution is at least involved in chronic decreases in tree vigor.

## Forest Effects Research

A large forestry research effort, the USFS/EPA Forest Response Program, was begun in 1985 to investigate the above forest condition changes and to determine the cause or causes. Results of this effort are just starting to be reported. The Forest Response Program is specifically designed to provide information for regulatory decision-making under the Clean Air Act (EPA), as well as for resource management decision-making (FS). Research is ongoing to investigate possible effects in eastern spruce-fir forests, southern commercial pines, eastern hardwoods, and western conifers. Another part of this program involves the design and establishment of a forest condition monitoring system for the U.S. to detect changes in forest health and productivity.

This forestry research program will operate through 1991 as shown in table 9, with parts of the program continuing well into the 1990s. Many answers to the original research questions are expected by 1990.

Table 9.—Forest Service/EPA forest response program major outputs

Product	Completion Date
Evaluation of the Extent and Magnitude of Recent Changes in Forest Condition	12/88
Evaluation of the Role of Non-Air Pollution Factors in Growth Reduction and Visible Decline	12/88
Quantitative Estimates of Seedling Response to Sulfur, Nitrogen, and Associated Pollutants in Forest Damage	4/88, then 4/89 update
Evaluation of the Roles of Sulfur, Nitrogen, and Associated Pollutants in Forest Damage	9/89 4/91
Projection of Forest Response to Alternative Deposition Levels	12/91

## CHAPTER 2: THE NORTH AND THE GREAT PLAINS

### LOCATION AND CHARACTERISTICS

The Great Plains Section is included with the North Section in this chapter because the forest ecosystems found in the Great Plains are more closely aligned with those found in the North than with those in the Rocky Mountains. The tables in the previous section group the Great Plains Section with the Rocky Mountains Section; however, in order to facilitate comparison with similar tables published during the last national Assessment, dated 1977 (USDA Forest Service 1981). The Great Plains Section is composed of 4 States (Kansas, Nebraska, North Dakota, and South Dakota). In this Chapter, the term "the area" will be used to describe the joint North and Great Plains Sections.

The North Section includes 20 states in the northeastern and north central parts of the United States (fig. 2). The North is further divided into two regions—Northeast and North Central. The area stretches from the Atlantic seaboard in the east to the prairies in the west; from the Ohio river, the Appalachian highlands, and the Northern Piedmont in the south to the Canadian border and the Great Lakes in the north. The more northern states of the area have moderately long, relatively severe winters. Annual precipitation is moderate and ranges from 25 to 45 inches; often half of this precipitation comes as snow. Short growing seasons of 100-140 frost-free days place limits on agricultural production. Much of this area has been glaciated and glacial landforms are common. The soils are generally well suited for forests. Most soils are acid and strongly leached, with an upper layer of organic matter. Soils with high water tables are common in many areas.

The states in the southern half of the area have cold winters and warm summers. Precipitation is greater than in the northern half and ranges from 35 to 60 inches. Most of the precipitation comes in the summer months. Growing seasons of 120-200 frost-free days and favorable soils produce some of the Nation's most productive agricultural lands. Most of the area is rolling or nearly flat, but the Appalachian mountains in the east (reaching from West Virginia to Maine) have steep slopes and elevations up to 3,000 feet. Many of the soils are low in bases and have subsurface horizons of clay accumulation. Soils are usually moist but during the summer are dry part of the time.

### FOREST LAND

#### Ecosystems

The 607 million acres of land in the North and Great Plains include 169.7 million acres of forest land (table

1), 28% of the total, of which 162.8 million acres are unreserved. Ninety-three percent of the forest land (158.2 million acres) is timberland, and 4% (6.7 million acres) is reserved timberland. Much of this forest land, especially in the Northeast Region, lies close to densely populated areas and receives intensive pressure from a wide array of forest users. Controversy sometimes flares as land managers and land users disagree over the future of these closely-watched forests.

Because most of the North Section, except for the prairie fringe in the western portions of Minnesota, Iowa, and Missouri, was originally forested, these lands tend to revert back to forests if disturbed, then allowed to stand idle. In the Northeast Region this process has occurred for several decades, and forest area has increased because of abandoned cropland and pasture returning to forest. In the North Central Region gains in forest area have been noticed more recently, and result largely from land formerly classed as wooded pasture no longer being grazed because of intensified feeding of cattle in feedlots.

**Oak-hickory.**—This ecosystem is the largest in the area with 47.8 million acres of unreserved forest land or 29% of the total (table 10). Generally, the oak-hickory ecosystem grows in a wide band along the southern portion of the area and joins the maple-beech-birch ecosystem to the north (figs. 5 and 10). The ecosystem may be broken down into smaller associations to reflect the species mix. Hickories are a small but consistent component. Stands closer to the maple-beech-birch transition line tend to be stocked more heavily with species other than oaks and hickories, such as ash, basswood, sugar maple and elm.

Benefits of oak-hickory forests range from providing habitat for squirrels, wild turkeys and other mast-eaters, to providing durable, beautifully-grained lumber for furniture, cabinets and flooring. High quality white oak is especially prized in European markets. Management of oak-hickory stands is impeded by the difficulty of regenerating oaks, and the continuing problem of a scarcity of markets for less desirable hardwoods which comprise a sizeable part of many stands.

**Maple-beech-birch.**—This ecosystem is the second largest in the area with 43.4 million acres, 27% of the unreserved forest. The area of this ecosystem is generally increasing because the major species are long-lived and shade-tolerant. If present in sufficient numbers in the understory of other ecosystems that are disturbed, these species may take over the site. Sugar maple, yellow birch, and basswood are important components of the ecosystem and are valuable as forest products. Red maple is less valuable but is fast-growing and aggressive. It is rapidly expanding its role in the ecosystem, particularly in the Northeast.

Table 10.—Area of unreserved forest land (thousand acres) in the North and Great Plains Sections by region and forest ecosystem, 1987

Forest ecosystem	Total North and Great Plains	North Section			Great Plains Section
		Total	Northeast Region	North Central Region	
Oak-hickory	47,783	47,073	23,927	23,146	710
Maple-beech-birch	43,395	43,247	26,836	16,411	148
Spruce-fir	18,857	18,840	10,262	8,578	17
Aspen-birch	17,938	17,754	3,174	14,580	184
White-red-jack pine	13,483	11,966	7,917	4,049	1,517
Elm-ash-cottonwood	11,856	10,546	3,784	6,762	1,310
Oak-pine	3,672	3,555	2,640	915	117
Loblolly-shortleaf pine	2,400	2,398	1,725	673	2
Oak-gum-cypress	797	797	363	434	—
Other	32	—	—	—	32
Nonstocked	2,571	2,449	636	1,813	122
All ecosystems	162,784	158,625	81,264	77,361	4,159



Figure 10.—An oak-hickory sawtimber stand.

The wide diversity of tree, shrub and forb species in maple-beech-birch stands make this ecosystem an important provider of a esthetic, wildlife, and recreational resources.

**Spruce-fir.**—Third in size in the area is the spruce-fir ecosystem with 18.9 million acres, 12% of the available forest. Spruce-fir stands are most dominant in Maine where they form large continuous blocks and comprise 43% of the North's spruce-fir total area. The remainder

is generally in smaller pockets scattered throughout the northern reaches of the maple-beech-birch ecosystem in the Northeast and in the extreme north of the three Lake States (Minnesota, Wisconsin, and Michigan).

Spruce-fir stands provide many forest products, perhaps most importantly, pulpwood. The fact that this ecosystem is generally remote and removed from urban areas makes it a precious recreational resource.

**Aspen-birch.**—The aspen-birch ecosystem extends over 17.9 million acres of available forest in the North and Great Plains—the fourth largest area. Located primarily (81% of the area) in the northern portion of the three Lake States, there are also sizeable areas of aspen-birch in the northern tier of the Northeastern States. Aspen-birch is a pioneer ecosystem, reclothing the land after major disturbances such as fire or heavy logging. Trees are short-lived and stands often revert to another forest type unless they are clearcut, which assures the continuation of the type. The aspen-birch area has been in decline because most stands were not managed until development of technology using aspen to produce waferboard. Since then, more stands are being clearcut and area losses are probably being slowed. Aspen-birch stands provide excellent wildlife habitat, especially for ruffed grouse, deer, and moose.

**White-red-jack pine.**—This ecosystem ranks fifth in size in the area with 13.5 million acres. It occurs scattered throughout the northern tier of states—remnants of the vast pineries of the past that supported a softwood lumber industry responsible for much of the construction in the Northeast and Midwest during the late 1800s and early 1900s. In the eastern range of the ecosystem, white pine and hemlock are the most important components; but in the western range, red and jack pines predominate. The pines have traditionally been valued for forest products, from saw logs to pulpwood to poles. And pines, especially mature trees, are an essential ingredient in the enjoyment of the landscape by outdoor recreationists of all kinds. Much of the tree planting done in the North involves pines, chiefly red and white pines.

**Elm-ash-cottonwood.**—Stands in this ecosystem grow scattered widely on 11.9 million acres throughout the area. The ecosystem is generally found along moist river and stream bottoms, and in or around swamps, gullies, and small depressions of slow drainage. The large mix of species in this type assures that stand composition will change quickly. Dutch elm disease has reduced the amount of elm in stands, and other aggressive species, such as red maple, sometimes fill in behind it. Most of the species associated with the ecosystem are not highly valued for timber products except for the ash species, which are prized for tool handles and sports equipment. Elm-ash-cottonwood stands are highly valued for helping to prevent erosion on moist, vulnerable soils, for providing habitat for many game and nongame species, and for their bright colors in the fall.

Other ecosystems in the area include oak-pine (3.7 million acres), loblolly-shortleaf pine (2.4 million acres), and oak-gum-cypress (0.8 million acres). These ecosystems occur on the southern edge of the North Section, and are discussed in more detail in the next section. Nonstocked forest land accounts for the remaining 2.6 million acres.

### Ownership

Although there is much variation among states, in 1987 about 80% of all timberland in the North and Great Plains was held by private individuals or firms (fig. 11). An estimated 3.3 million private owners hold 126

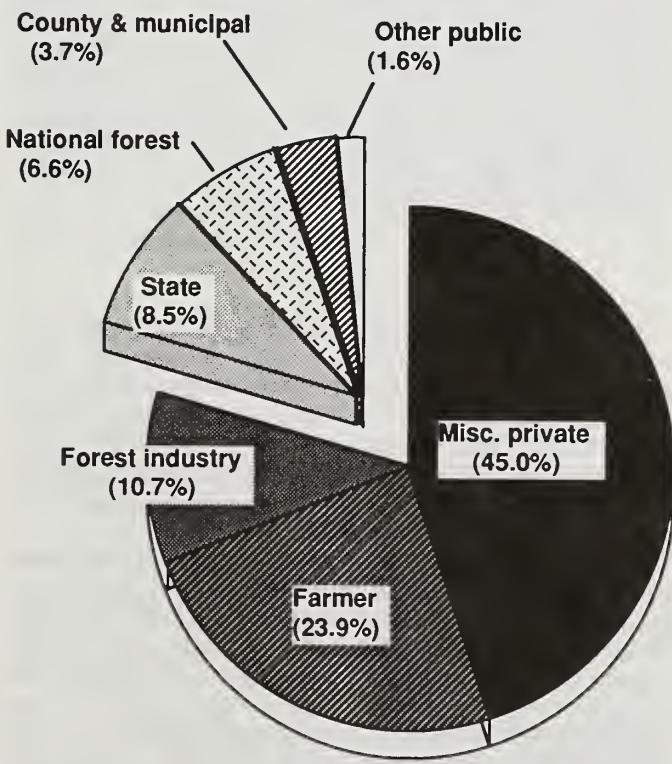


Figure 11.—Area of timberland in North and Great Plains sections, by ownership, 1987.

million acres of timberland. Federal, state and other public ownerships account for the remaining 20% of the timberland, over 32 million acres.

A profile of the private owners shows that 87% of them are represented by a single individual or a husband-and-wife team. These persons hold 67% of the private forest land. Six percent of the private owners are in some other kind of family partnership (involving other family members or family corporations), and they hold 9% of the private forest. Another 3.5% of the private owners consists of corporations (other than family corporations), accounting for 19% of the private forest.

The remaining 3.5% of private owners is a mix of non-family partnerships, noncorporate sport and recreation clubs, and undivided estates, and collectively accounts for 5% of the private forest area.

Within the single individual or husband-and-wife team owner group mentioned above, farmers own more forest land than any other owner. Farmers control nearly 18% of the private forest land, although they represent less than 4% of the private owners (these figures do not include land owned by farmers who are part-time or retired, whose land is included in the total farmer-owned lands in this report). Retired people own nearly 15% of the private forest and represent 20% of the forest landowners. White collar workers own 17% of the private forest land, although they account for the largest proportion of private owners—36%. The remaining individual owners are blue collar workers, housewives, and other private owners, including service workers. This group holds 18% of the private forest land and represents 25% of the private owners.

Forest industries, comprising most of the corporate forest land, own 17.0 million acres in the North and Great Plains. Other corporations owning sizeable acreages of forest land include mining and drilling companies, insurance companies, real estate firms, railroads, corporate farms, public utilities, youth organizations, and sport and recreation clubs.

The more forest land an individual owns, the more likely he or she is to manage timber actively. Even in the heavily populated Northeast most owners of more than 500 acres of forest land intend to harvest timber from their land at some time in the future. Nearly one-third of the private forest land in the North is in ownerships greater than 500 acres, and about half of this is concentrated in the hands of owners who hold more than 10,000 acres of forest land. Most of these are forest-based industries or are groups that employ foresters and actively manage their forest lands. An additional 40% of the private forest land is in ownerships of 100 to 500 acres. Many of these ownerships could produce substantial amounts of timber on a continuing basis. The remaining 27% of the private forest land is in ownerships of fewer than 100 acres. These lands may not be the most important for timber production, but they may be very important for other forest values. Location, size, and owner objectives may effectively remove these lands from the timber-producing base.

Some 10.4 million acres of timberland are located in national forests in the area. This area is virtually

unchanged since 1977 despite increases in wilderness designations and areas deemed under custodial management as a result of the forest planning process. Federal lands other than national forests in the area amount to 1.5 million acres. State, county, municipal, and Indian forests are an additional 20.3 million acres. Many of these latter holdings are located in the Lake States and are lands that reverted to public ownership, through tax delinquency, during the depression years of the 1930s. In the Northeast, many of these lands are important watersheds for municipalities. They are also crucial for cold water fisheries and wildlife habitat.

### Productivity

Sixty-two percent of the unreserved forest land in the area is capable of producing 50 cubic feet of wood or more per acre per year (fig. 12). The most productive land—land capable of producing over 120 cubic feet per acre annually—accounts for 4% of the total unreserved forest area. Highly productive land, capable of producing 85 to 120 cubic feet of wood annually on each acre, makes up 18% of the total. And moderately productive land, capable of producing 50 to 85 cubic feet per acre, represents 40%.

Forest land of marginal productive capacity, 20 to 50 cubic feet, accounts for 35% of the total. Unproductive forest land, incapable of producing 20 cubic feet per acre per year, occurs on 3% of the total.

Productivity is somewhat higher in the Northeast than in the North Central Region. Sixty-six percent of the Northeast's forest land (53.5 million acres) can produce in excess of 50 cubic feet, compared to 60% (46.1 million acres) in the North Central Region. Sites with poorer productive capability are often found in areas of poor drainage, such as the swamps and bogs supporting black spruce, northern white-cedar, and tamarack, located along the northern edge of the northern tier of states. Shallow soils and areas of hardpan in Missouri make this the state with the largest area of unreserved forest land incapable of producing annually more than 50 cubic feet per acre in the area (8.5 million acres or 69% of the total). Eastern redcedar, post oak-blackjack oak, black oak-scarlet oak, and white oak associations all occupy large areas of marginal or unproductive sites in Missouri. Substantial areas of dry, shallow soils produce sites with low productivity in the oak-hickory ecosystem in Pennsylvania and West Virginia, and in the maple-beech-birch ecosystem in Maine, Michigan, Vermont, New York, Wisconsin, New Hampshire, and Pennsylvania. Poorly drained soils contribute to the large area of sites with low productivity in the spruce-fir ecosystem in Minnesota, Maine, and Michigan.

Productivity is lowest in the Great Plains Section where only 29% of the unreserved forest land (1.2 million acres) can produce more than 50 cubic feet per acre annually.

A crude estimate of average potential productivity on unreserved forest land for the North and Great Plains combined is 58 cubic feet per acre per year. This estimate

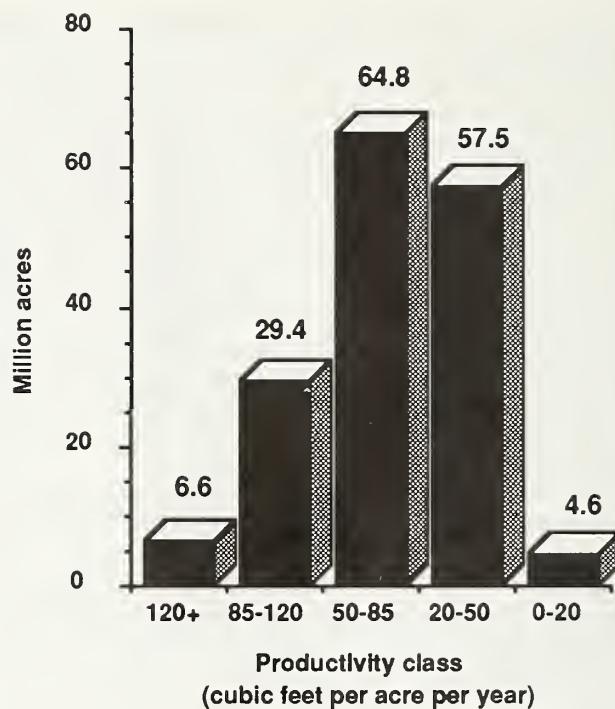


Figure 12.—Area of unreserved forest land in North and Great Plains sections, by productivity class, 1987.

is made by weighting the mid-point of each productivity class (excluding the 0 to 20 cubic feet class) by the number of acres in that class, then discounting the result by 10% to adjust for holes in the forest canopy caused by rocky outcrops, marshes, buildings, etc. that prevent yields over large areas from reaching predicted levels. This estimate compares with the average net annual growth per acre on timberland in 1986 for the area of 35 cubic feet. Actual productivity will approach the potential as stocking levels improve and as forest management is more widely practiced.

### Use

Forest land in the North and Great Plains produces a wide range of timber products, from saw logs and pulpwood to posts and fuelwood. But timber products are just one of many uses of the forest. Recreation demand grows each year. Camping, hiking, fishing, cross-country skiing, bird watching, snowmobiling and hunting are some of the ways people in the area use forest land to renew themselves.

Many wildlife species exist in a forest habitat, and their needs must be considered in managing and using the land. A classic example is the Kirtland's warbler, an endangered song bird that nests only in seedling-sapling stands of jack pine in a limited area of the Northern Lower Peninsula of Michigan. Without a continual supply of these trees in the small geographic area required, the bird could become extinct.

Urban forests, are also becoming an increasingly important resource. This is especially true in the Northeast,

but it is generally true over much of the area. Urban forests are made up of several components including street trees, volunteer and planted exotic and native yard trees, islands of planted, residual or second-growth forests, and islands of pioneer tree communities on abandoned land (Rowntree 1987).

In the Northeast, some urban forests have the same characteristics as timberland, the only difference being their urban orientation. In past inventories urban forests have been classed as noncommercial forest land within urban areas that were surrounded by urban development (not parks). Some estimates of urban forests are now based on forest areas meeting timberland definition, but falling within Bureau of Census tracts with population densities of greater than 500 persons per square mile (urban areas). This new criterion resulted in a much larger estimate of urban forest area (Powell and Kingsley 1980).

In the North Central Region and Great Plains Section there are no reliable estimates of urban forest area. However, urban forests are a significant component of many metropolitan areas. They occur as county parks, forest preserves, nature areas, municipal watersheds, unused parcels of land, street trees, wooded river banks, power-line corridors and cemeteries.

The great diversity of the urban forest makes it difficult to generalize about the potential benefits of management, or limitations of management practices. It is probably safe to say that the greatest benefits from urban forests are from recreation, esthetics, and other improvements in the general quality of urban life. These improvements may take the form of physical effects on the environment (e.g. moderating temperature extremes), as well as improvements in psychological well-being. Studies have shown that trees have a calming effect on people, which results in measurable reductions in physiological stress (Ulrich 1981, 1984).

Political and economic factors make it unlikely that urban forests can contribute significantly to the region's production of timber. However, some trees will be harvested as urban forests are converted to home sites, shopping malls, parking lots, etc.

### Trends in Forest Area

The area in timberland in New England and the Middle Atlantic states increased steadily from 1952 to 1987. Forest areas in wilderness, parks, and natural areas on national forest and state-owned land also increased during this same time period. Some land use changes are not permanent. The land cleared for crops today or many years ago can revert to forest cover in a short period of time if left uncultivated. Conversely, cropland put into a Christmas tree plantation or planted to trees can return to its previous use. Land cleared for mining and waste disposal can be restored to cropland, pasture, or forest use.

In the North Central Region and Great Plains Section, trends are mixed. Some states, such as Wisconsin, Illinois, Indiana, and Kansas, had shown steady declines in timberland area between 1952 and 1977. But between

1977 and 1987 they showed small increases in area, primarily due to the reversion of wooded pasture to timberland because of improved stocking levels on previously grazed land. Other states show a continual decline in area of timberland, and 50-year projections suggest declines for all states in these areas.

The forest is viewed by some as a residual land use. People in agriculture look for potential cropland needs to be supplied from the forest land base. To the home builder, tree cover can be a hindrance to site preparation prior to construction and trees can be a disposal problem. Other builders seek wooded acres to subdivide and to charge premium prices for wooded house lots.

The changing nature of agriculture in the Northeast has had the greatest effect on the area in forest land. Most of the increase in forest land can be directly linked to the decrease in farm area, particularly the dairy sector of the farm community. Many factors are responsible for the change— inflation, capital costs, nonfarm employment, comparatively poor soils, transportation costs. The area in pasture has continued to decline across the region, while cropland areas have leveled off or increased in many areas.

Future resource demands, economic considerations, and cultural and societal factors will influence future forest area changes. The demographic structure of the population and of the resource owners could produce dramatic changes. The most significant of these demographic changes are projected to be (1) the decline in population growth, (2) the general aging of the population and resource owners, and (3) the passage of the baby boom generation to retirement age. Economic considerations include the size and productivity of the forest holding. Forest holdings that are too small or support low value timber may not remain in the forest land base unless they are held for other reasons, such as recreation, wildlife, or watershed values. Cultural and societal factors such as public concern for environmental quality can decrease forest land conversions to agricultural land use. The pine lands legislation in New Jersey is a prime example. This act has almost stopped the loss of forest and agricultural land to urban uses. Another example is township-level harvesting regulations that have changed how land can be used.

Sorting out the implications of current changes in land use is no easy task. Urban areas have doubled in size. The area in farms has declined rapidly. Forests have gained in some areas while losing ground in others. Technological changes in the production, marketing, and utilization of forest and agricultural products and their substitutes will have major impacts. The strength of the American dollar relative to other world currencies, trade deficits, inflation, and other economic issues will come into play. The attitudes of farmers, forest-land owners, and others towards timber management will have an impact on how forest lands are utilized. Other factors, such as the attractiveness of local business climates and living environments will have much to say in how future outlets for raw materials from forest land will develop. By keeping track of what is going on, we will be better able to adapt to changes and plan for the future.

## RANGELANDS

A total of 78.0 million acres in the North and Great Plains are classified as rangeland (13% of the land area) (table 1). Almost all of it (77.6 million acres) is in the 4 Great Plains States—Kansas, Nebraska, North Dakota, and South Dakota. The remainder (0.4 million acres) is primarily in Minnesota and Missouri, with very small areas in New York, Wisconsin, and Iowa.

The Great Plains are known for hot, dry summers and cold, windy winters. Periodic droughts are common and precipitation is sparse. Stringers of hardwood trees (primarily in the elm-ash-cottonwood ecosystem) follow drainage systems that lace through the flat grasslands.

Great Plains rangeland is composed of two major ecosystems: the plains grasslands and the prairie. The plains grasslands is often called the short- or mixed-grass prairie and extends eastward from the foothills of the Rocky Mountains to approximately the 100th meridian, which roughly bisects the four Great Plains states (Stoddart et al. 1975). The western half of the four states, then, is part of the plains grasslands.

Short, warm-season grasses and grasses of medium stature predominate in the plains grassland, such as blue grama, western wheatgrass, needlegrass, threadleaf sedge, and needle and thread grass. Forbs and shrubs are scattered lightly over the grasslands. Plains grasses are noted for their high nutritional value and for their ability to cure well on the range. Forage may be in short supply in the spring because most species are warm-season plants. Plains grasses are resistant to heavy grazing, but with over grazing give way to weedy plants.

The prairie ecosystem, which lies between the deciduous forests of the East and the plains grasslands of the West, is also roughly delineated by elevation. The western boundary is approximately 1,500 feet above sea level, and the eastern boundary is about 500 feet.

The prairie, also known as the tall-grass or true prairie, once included much of what is now the Nation's corn belt. Only the driest portions and those parts underlain by soils too rocky for cultivation remain as the prairie ecosystem today. Big bluestem, which may reach a height of 5 to 6 feet on lowland areas, Canada wildrye, Indiangrass, switchgrass, little bluestem, and sideoats grama are some of the major grass species in the ecosystem. Large numbers of flowering forbs are present in the grass stands, but are overshadowed by the grasses. Tall-grass vegetation does not cure well on the range. Almost all grass species lose much of their nutritive value after they mature, and during the winter, domestic animals cannot thrive on these grasses unless they are fed additional protein supplements. Heavy grazing on tall grasses may result in the replacement of desirable by less desirable species (Branson 1985).

Table 11.—Ownership of Rangeland (thousand acres) in the North and Great Plains

Owner group	Area	Percent of total
Forest Service	2,617	3
Bureau of Land Management	323	1
Other Federal	732	1
Total Federal	3,672	5
Non-Federal	74,334	95
Total all owners	78,006	100

Bison once grazed the plains grasslands and the western edge of the prairie. The pronghorn antelope is still present, as is the coyote, jackrabbit, prairie dog and ground squirrel. The potholes of the northern portion of the prairie ecosystem provide an important breeding area for many species of migrating waterfowl. Mourning doves are abundant, especially near shelterbelt plantings, and sharptailed grouse and greater prairie chickens are also found in fair numbers.

Ninety-five percent (74.3 million acres) of the rangeland in the North and Great Plains is in nonfederal ownership (table 11).

## WATER AREAS

Water areas in the North and Great Plains total 57.8 million acres or 54% of the Nation's water (table 1). Of the 665 million acres of land and water in the area, water accounts for 8.7%.

The North Central Region, led by Michigan, contains 75% of the water in the area. Other states with large areas of water include Wisconsin, Minnesota, New York, and Ohio. The Great Lakes, bays and estuaries on the Atlantic coast, large and small natural lakes, particularly those in the northern half of the northern tier of states, and the tributaries of the major rivers, such as the Missouri, Mississippi, and Ohio, make up most of the water area. Water impoundments, ponds, and streams comprise the remaining area of water. Water areas provide valuable fish and wildlife habitat as well as breeding and resting areas for migratory waterfowl. Water-based recreation is a large and growing use of the resource—from paddling a canoe across the glassy surface of a remote lake in the solitude of the Boundary Waters Canoe Area Wilderness in Minnesota to tubing down a Pennsylvania river that meanders through agricultural land and farm woodlots. Domestic and industrial uses round out the ways the water resource is consumed.

## CHAPTER 3: THE SOUTH

### LOCATION AND CHARACTERISTICS

The South includes 13 states of the Southeastern and South Central United States (fig. 2). The area stretches from Virginia southward and westward along the Atlantic and Gulf seaboards to Texas, and includes the interior states of Kentucky, Tennessee, Arkansas, and Oklahoma. This section is characterized by a variety of climatic and edaphic conditions that relate to its diverse physiography. The South covers portions of four major physiographic divisions: the Atlantic Plain, the Appalachian Highlands, the Interior Highlands, and the Interior Plains (Fennemann 1938).

The Atlantic Plain dominates the land area and consists of Coastal Plain provinces located along the Atlantic and Gulf coasts and on the alluvial plain of the Mississippi River. The climate is subtropical with rainfall averaging from 40 to 60 inches annually (USDA Forest Service 1969). The section has a long growing season, but is subject to harsh shifts in weather that include droughts, tropical storms, tornadoes, and glaze storms. Topography is relatively flat along the coast and hilly in the upper portions of the South Central Region (fig. 13). Poorly-drained low areas dissect the Coastal Plain along the many rivers and streams that flow through the area. Soils, ranging from sands to clay, are usually acidic and so strongly leached that organic matter and nutrient levels are low (Barrett 1980). Exceptions occur in bottomland areas that are rich in alluvial deposits and in the Brown Loam Bluffs adjacent to the Mississippi River Valley.

The Appalachian Highlands physiographic division includes the Piedmont, Mountain, and Plateau provinces. The Piedmont province lies parallel to the southeastern Coastal Plain, extending from Virginia to Alabama. The Mountain and Plateau provinces are oriented in belts to the west of the Piedmont. They include, from east to west, the Blue Ridge province, the Valley and Ridge province, and the Appalachian Plateau province.

The Piedmont's topography is rolling, with elevations in the 300 to 1,200 foot range. Many creeks and streams flow from the Piedmont into the Coastal Plain. The climate is more like the Coastal Plain than the Mountain province, but varies somewhat from north to south. Rainfall averages from 40 to 50 inches per year. Soils generally contain more clay than in the Coastal Plain and are subject to erosion in many areas.

The Mountain and Plateau provinces exhibit a variety of topographic features. Mountains of the Blue Ridge province are the highest, usually from 3,000 to 4,000 feet in elevation, with some peaks over 6,000 feet. The Valley and Ridge province has mountains from 2,000 to 4,000 feet that occur in long narrow belts. The

Appalachian Plateaus have mountains that range from 2,000 to 4,500 feet. The Mountain and Plateau provinces typically have shorter growing seasons and cooler winter temperatures than the Piedmont and Coastal Plain. Rainfall averages between 45 and 55 inches per year. Soils are variable, depending on physiography, parent material, vegetation, and climate (Barrett 1980).

The Interior Highlands division encompasses the lower reaches of the Ozark Plateaus (including the Boston Mountains), and the Ouachita Mountains. Elevations vary from 500 feet in the Arkansas River Valley to more than 2,800 feet in the Ouachitas. The climate is humid with cool winters and hot summers. Rainfall averages roughly 45 inches per year. Soils are generally freely drained, acidic, and humus-poor (Barrett 1980).

The Interior Plains division is situated in the northwestern and southwestern portion of the South. The Interior Plains includes the Interior Low Plateaus of Kentucky, Tennessee and north Alabama, and the Central



Figure 13.—The southern landscape ranges from coastal wetlands to rugged mountains.

Lowland and Great Plains provinces of Oklahoma and Texas.

Topography of the Interior Low Plateaus ranges in elevation from 400 feet in the Nashville basin to 1,300 feet on the Highland Rim. Climatic conditions are similar to the mountains lying to the east. As with the mountains, soils vary considerably.

The Central Lowland and Great Plains provinces comprise the western portion of the South. The Central Lowlands of Oklahoma and Texas are made up of wide valleys with low relief. The Great Plains makes up the remaining land area, with topography ranging from flat to rolling plains. The climate changes from arid in the west to humid in the east.

## FOREST LAND

### Ecosystems

The South is heavily forested from Virginia to the forest's limit in Texas and Oklahoma. Forest land totals 203 million acres or 38% of the total land area (table 1, fig. 4). If the nontimbered western portions of Texas and Oklahoma are included, the percentage of forest increases to 54%. Five of the southern states are more than 60% forested, and most of the remaining states are at least 50% forested.

The South's 62 million acres of pine forest continue to be a major source of softwood fiber for the world (table 12). About two-thirds of the pine forest is natural in origin with the remainder consisting of planted pine stands. Many of the South's natural pine stands are now reaching maturity and are being harvested (fig. 14). On industrial properties, natural stands are typically replaced with intensively managed pine plantations. Planted pine stands currently make up 60% of industry's pine forest in the South. Harvested nonindustrial private tracts often lack adequate regeneration.

Several programs have been implemented to offset the loss of pine forests. Cost-sharing for tree planting and timber stand improvement is available through the federally-funded Forestry Incentives Program (FIP) and Agricultural Conservation Program (ACP). Rental payments are available for converting marginal cropland to trees as part of the Conservation Reserve Program (CRP) of the 1985 Farm Bill. Various state-level programs also promote pine regeneration.

**Loblolly-shortleaf pine.**—These forests are the South's most prevalent pine ecosystem, accounting for three-fourths of the total pine forest or 46 million acres (table 12). This ecosystem consists of pure loblolly stands, pure shortleaf stands, and mixtures of the two intermingled with other southern pine species. Natural stands often have a significant hardwood component.

Loblolly pine is the dominant species of the Coastal Plain and Piedmont provinces (McWilliams and Birdsey 1983, Sheffield and Knight 1982). It has been favored for new stand establishment over the past 30 years. Forest managers prefer loblolly because it usually exhibits rapid growth in the juvenile years. Because of its widespread occurrence, the loblolly pine ecosystem is a major supplier of timber, wildlife, and recreation resources.

Shortleaf pine is the second most common pine, but has a much wider distribution than loblolly (McWilliams et al. 1986). Shortleaf occurs in all physiographic divisions of the South; hence, it is an especially important timber species outside of loblolly's range. The heaviest concentration of shortleaf is found in the Ouachita Mountains of Arkansas. Texas, Mississippi, and Alabama are also important shortleaf pine states.

**Longleaf-slash pine.**—This ecosystem is important along the lower Coastal Plain. Longleaf-slash forests total 16 million acres, most of which are in Florida and southeast Georgia. The longleaf-slash pine ecosystem includes stands on a continuum from pure longleaf to pure slash pine.

Table 12.—Available forest land areas (thousand acres) in the South, by ecosystem and productivity class

Ecosystem	Total	Productivity class <sup>1</sup>				
		120+ cu.ft.	85 to 120 cu.ft.	50 to 85 cu.ft.	20 to 50 cu.ft.	0 to 20 cu.ft.
White-red-jack pine	514	276	102	118	18	0
Spruce-fir	18	0	0	9	9	0
Longleaf-slash pine	15,535	830	3,783	8,453	2,425	44
Loblolly-shortleaf pine	46,289	8,008	16,666	18,546	3,028	41
Oak-pine	27,799	4,413	8,754	11,624	2,984	24
Oak-hickory	74,262	5,740	18,344	33,501	12,974	3,703
Oak-gum-cypress	28,335	4,371	8,927	11,735	2,299	1,003
Elm-ash-cottonwood	3,007	627	1,078	1,152	150	0
Maple-beech-birch	877	109	206	415	146	1
Nonstocked	3,868	39	267	1,466	1,793	303
South total	200,504	24,413	58,127	87,019	25,826	5,119

<sup>1</sup>A measure of mean net annual growth obtainable in cubic feet per acre in fully stocked natural stands.



Figure 14.—Many of the South's natural pine stands are now reaching financial maturity and are being harvested.

Longleaf pine predominated over much of the lower South and up into the Appalachian Highlands prior to settlement. It was nearly eradicated following the "logging boom" of the early 1900s. A lack of information on regeneration techniques, the control of wildfire, and an indifferent attitude by the people were major causes of the decline (Croker 1987). Longleaf sites were usually reforested with loblolly or shortleaf pines. The decline of longleaf continued until very recently. Improved awareness of longleaf's benefits has led to the beginning of a comeback for the species.

Slash pine occurs naturally on wetter sites and sites protected from wildfire, but has been planted widely over the past 30 years. Planting has spread slash pine well beyond its natural range, and over half of today's stands are planted (Sheffield et al. 1983). Slash pine currently dominates the longleaf-slash pine ecosystem.

**Oak-pine.**—This ecosystem covers 28 million acres and is comprised of forests in which upland hardwood species are dominant, but softwoods contribute at least 25% of the stands' stocking. Oak-pine stands are scattered across the South and are very common wherever

southern pine species are found. Oak-pine forests often originate on cutover pine sites with poor pine regeneration. Management of oak-pine forests offers an excellent low-cost alternative for the small private landowner (Phillips and Abercrombie 1987). The oak-pine ecosystem is important for timber, but is also outstanding in providing species richness, esthetic beauty, and wildlife habitat.

**Oak-hickory.**—These forests are the South's most extensive ecosystem, covering 74 million acres. Oak-hickory forests are represented by a diversity of species and sites (fig. 15). The most common mixture is the white oak-red oak-hickory association. Oak-hickory forests of the Coastal Plain are often the result of cutting practices that remove pine from pine and oak-pine stands leaving the stand to regenerate with hardwoods. The most productive oak-hickory sites of the Coastal Plain are found in the Brown Loam Bluffs of west Mississippi and west Tennessee. In the Mountain and Plateau provinces, oak-hickory forests are the primary supplier of wood, wildlife, recreation, and watershed protection. The most productive sites for timber, supporting mixed hardwood species, are the deep, well drained soils that occur on moderate slopes and cove sites (Barrett 1980). Along the western fringe of the timbered South are the post oak forests of Texas and Oklahoma. While relatively unproductive, this type provides a wealth of nontimber resources.



Figure 15.—Diverse oak-hickory forests are the South's most extensive ecosystem.

**Bottomland hardwoods.**—These forests are located throughout the South along watercourses and in low-lying, poorly drained areas. Heaviest concentrations occur in the Mississippi delta region and in Florida. Although they only occupy 16% of the total forest (31 million acres), bottomland forests contain some of the most valuable hardwood timber of the Atlantic Plain, as well as abundant wildlife habitat and recreation. Bottomland hardwoods include the oak-gum-cypress (28 million acres) and elm-ash-cottonwood (3 million acres) ecosystems.

Other ecosystems occur infrequently in the South. These include the white-red-jack pine, spruce-fir, maple-beech-birch, and pinyon-juniper ecosystems. Their importance stems from the unique habitats they contribute to the southern landscape. These ecosystems are described in detail in the North and Great Plains and Rocky Mountains sections.

### Ownership

Private owners control 90% of the timberland in the South, a total of 175 million acres (USDA Forest Service in press). The remaining 10% is divided among public owners including national forests, other federal, state, county, and municipal owners. The South's 33 national forests contain 6% of the forest land. At the state level, the national forest ownership ranges from 3% of the forest land in Alabama to 14% in Arkansas. Other major federal owners include the Department of Defense and the National Park Service.

Private owners are divided into nonindustrial private forest landowners and forest industry. Nonindustrial private owners are made up of farmers, other individuals, and corporations (other than forest industry). They hold 70% of the total private forest land area. Nonindustrial private owners have a highly diverse set of ownership objectives, from purely esthetic to economic. Most nonindustrial owners are aware of the value of their timber and are not averse to harvesting when offered a reasonable price. However, timber sales are often preempted where other forest resources are valued higher than timber. In general, nonindustrial private timberland receives less active forest management than forest industry timberland. Forest management is concentrated on larger tracts and on tracts that contain a high proportion of pine timber.

Forest industry controls 20% of the South's forest land. Forest industry stands are often concentrated on more productive sites with better stocking than nonindustrial private stands (McWilliams and Birdsey 1987). Also, a much higher proportion of forest industry land is in intensively managed pine plantations.

The distribution of privately-owned forest land follows a predictable pattern in the South. Nonindustrial forests are distributed relatively evenly across the section. Very often, forest industry's holdings are either in close proximity to a pulpmill or large sawmill, or situated on the more productive sites common in the pine belt (Rosson and Doolittle 1987).

### Productivity

The South's forest lands span the full range of productive capability. Some of the most extensive areas of highly productive forest lands in the United States are in this section. Long growing seasons, generally abundant rainfall, and mild climate, in combination with other favorable site conditions, often result in ideal conditions for forest growth. There are also extensive areas having a relatively low productive potential. Geologic formations and soils limit productivity in many cases. In others, the potential of today's forests has been significantly altered by human influence. A large portion of the South's land area has been in agricultural use one or more times since settlement. Many of these sites were depleted of nutrients and often suffered severe soil erosion before being abandoned. Most of these old field sites came back into forest cover and form the backbone of today's forest land.

A higher proportion of the South's forest land is in high timber productivity classes relative to other sections of the United States. About 24 million acres, or 12% of the available forest land, are capable of producing more than 120 cubic feet of wood per acre per year. Another 29% is capable of producing between 85 and 120 cubic feet annually. Together, these two classes constitute the above average sites and account for more than 40% of the available forest land (table 12). About 70% of these most productive sites are located in the South Central Region. Sites capable of producing 50 to 85 cubic feet per acre annually account for 43% of the forest land. Nearly 56% of these moderately productive sites are in the Southeast Region. Forest lands of low productive potential total 26 million acres and are about equally divided between the Southeast and South Central Regions. Most of these lands in the 20 to 50 cubic feet category of production are concentrated in the oak-hickory ecosystem. About 5 million acres of forest land in the South are incapable of producing 20 cubic feet of wood per acre annually. These areas include the post oak forests of Oklahoma and Texas and poorly drained lowland hardwood forests, primarily in Florida.

The potential yields suggested by the site productivity classes are generally not attained. For example, the average potential productivity determined by weighting the productivity classes by acres is about 88 cubic feet per acre per year for the South (excluding woodland—the 0 to 20 class). Yet, current net annual growth per acre averages less than 54 cubic feet. Only a small portion of the forest land is fully stocked with vigorous trees of the ideal species for timber production. Many acres are understocked and need various treatments in order to produce up to their potential.

The gap between potential and realized productivity in the South appears to be widening, at least temporarily. Net annual growth per acre of timberland has dropped from 57 to 54 cubic feet per acre during the past 10 years. In fact, reduced per-acre growth has been recorded in each of the last six southern states inventoried (Alabama, Louisiana, Oklahoma, South Carolina, Texas, and Virginia). Although extensive areas of productive pine

plantations are being established, most are still so young that productivity gains from these management efforts are not yet fully realized. Reduced levels of growth are concentrated in natural stands, primarily on nonindustrial private forest land. This downturn in net annual growth in the South has been documented in other studies (Knight 1987, and USDA Forest Service 1988).

The productivity of the South's forests for uses other than timber production is also diverse. Little data is available to assess these productive potentials. High productivity for other uses is complementary with timber production in some cases and not in others. Forests which are of low productivity for timber can be highly valuable for wildlife, recreation, browse production, and ecological diversity.

### Use

The South's forest lands provide a range of benefits to society beyond basic timber products. Forests throughout the area provide habitat for a diversity of wildlife and fish species. Both nongame and game species alike depend on Southern forests for their existence. The importance of managing and conserving forest habitats for threatened and endangered species such as red-cockaded woodpeckers and bald eagles has recently been emphasized.

Large numbers of people are using Southern forests for recreational purposes. Although populations and associated urban areas are expanding, the South's rural charm has been maintained. Hunting, fishing, camping, and hiking are still very popular recreational pursuits in the South. Winter vacation spots abound because of the warm climate, especially along the Gulf and Atlantic coastlines. Forests add to the scenic beauty of mountainous areas, which draw millions of visitors each year. Wilderness areas provide another kind of recreative experience for large numbers of people.

The South's forest lands are also an important source of forage for cattle. With the exception of some portions of Florida, the degree of forest use for grazing is generally light in the Southeast, averaging under 10% of the forest land. Forest grazing use increases substantially as one goes west through the South Central area. More than one-fourth of the forest land in eastern Texas and Oklahoma is used for grazing.

Most of the South's forest lands provide for some combination of uses. (fig. 16). The types of use depend on the character of the land, past history, ownership, management objectives, and surrounding land uses. Southern forest lands are generally very accessible due to the nature of the landscape and land use histories. Roads are abundant and their close proximity to most forest land encourages a frequent and varied mix of uses.

Rural populations have always utilized forests extensively because they were nearby. Although much of today's forest land is still intermingled with agricultural uses, urban development is becoming an increasingly dominant component of the southern landscape. In the Southeast, one out of every five acres of forest land is



Figure 16.—Bottomland hardwoods forests provide valuable hardwood timber, wildlife habitat, and recreational opportunities.

within one mile of concentrations of urban development, either residential or industrial. In the South Central Region, one out of ten acres of forest land is within one mile of urban or developed land.

### Trends in Forest Area

Some two to three centuries ago, almost all land area in the South was in forest cover. The current forest resource represents a substantial erosion of that original base. Although the long-term trend has been toward less forest land, the reductions have been neither constant nor uniform. The magnitude and direction of change have been driven by a number of factors, including the need for living space and food, timber harvesting, the effects of fire control, and in more recent decades, the results of silvicultural practices. Perhaps the most influential factor driving change in forest land over the long term is the expansion and contraction of the region's agricultural land base (Healy 1985).

As the South was settled, agricultural land became an increasingly prominent part of the landscape. The associated reduction in forest area accelerated in the late 1800s with harvesting of the old-growth forests (USDA Forest Service 1988). Around 1920, increases in forest

area began in response to agricultural land abandonment, reduced timber harvesting, and efforts to regenerate forest lands. The rate of agricultural land abandonment and succession to forest was especially high during the depression years of the 1930's and after World War II. Much of the land reverting to forest on retired cropland and pasture was dominated by southern pine species.

In 1952, forests covered some 208 million acres of the South's land area. In the decade that followed, the trend toward farmland abandonment and reversion to forest cover continued. During the late 1950s and early 1960s, some 2 million acres of agricultural lands were planted to trees (USDA Forest Service 1980). By 1962, forest area had increased by 7 million acres to 215 million acres. After 1962, forest area in the South began to decline again, dropping to 208 million acres in 1970, 204 million acres in 1977, and 199 million acres in 1987. The rate of cropland abandonment slowed noticeably during the 1960s; thus, fewer acres were available to add to the forest base. In fact, forest land clearing for new cropland and pasture began to occur at an increasing rate. At first much of the clearing was concentrated in the Mississippi delta where bottomland hardwood stands were cleared for soybean production. Later, during the 1970s and early 1980s, concentrations of forest diversions for crop production spread more uniformly throughout the Coastal Plains of the South. Clearing for pasture occurred mostly in the upland areas of the South. Land area in urban and related uses has shot upward in the South during the past two to three decades, siphoning off significant areas of forest land. Both people and industry have migrated to the South in large numbers. During the 1970s and 1980s, most of the southern states experienced a net in migration of people (Healy 1985). These changes have increased withdrawals from forest land for living space and industrial sites.

A great deal of uncertainty surrounds the current forest resource and the rate at which it is changing. There are indications that the trends just described for the past 20 years might not continue unabated. The large-scale clearing of bottomland hardwoods for cropland in the Mississippi delta is not expected to continue at rates observed during the past two to three decades due to wetland conservation efforts and because much of the remaining forest area is not desirable for crop production due to the lack of flood control or drainage (Rudis and Birdsey 1986). Large-scale clearing for cropland along the southeastern Coastal Plain also appears to be tapering off for environmental and economic reasons.

The potential for forest land clearing because of growing population in the South is no doubt still large. However, the outlook for cropland needs is more uncertain (USDA Forest Service 1988). Unattractive economic returns from farming may well be creating a reservoir of land potentially available to add to the forest land base (Alig et al. 1986). Currently, many acres of marginal cropland and pasture in the South are being planted to trees as part of the Conservation Reserve Program (CRP) (fig. 17). This program could potentially put as many acres into forest cover as the Soil Bank program did 25



Figure 17.—Many acres of marginal cropland and pasture in the South are currently being planted to trees.

years ago. The full impact of the CRP and possible extent and duration of increased farmland abandonment will not be known for several years.

## RANGELANDS

The South has 116 million acres of rangeland (table 1). Eighty-three percent of the rangeland is located in Texas. Oklahoma and Florida are the only other States with significant areas of range (14 and 4 million acres, respectively).

The South's rangeland is split between shrubland and grassland ecosystems. Four shrubland ecosystems are present in Oklahoma and Texas. The most prominent shrubland ecosystem is the Texas savanna situated in southern Texas. This ecosystem is a savanna with low trees and shrubs, and short to medium tall grasses. Mesquite is the most common woody plant. To the west is the southwestern shrubsteppe ecosystem, which is typified by short grasses mixed with shrubs at varying levels of intensity. The shinnery ecosystem is a midgrass

prairie with occasional stands of shrubs and low trees, occupying less than 5% of the South's rangeland. A small area of the desert shrub ecosystem is also present in Texas (Garrison et al. 1977).

The South's grasslands include four ecosystems: plains grasslands, prairie, desert grasslands in Oklahoma and Texas, and wet grasslands found in the South's coastal areas. The plains grasslands ecosystem, or Great Plains, is the largest rangeland ecosystem in the South and the Nation. In the South, it is located in northern Texas and western Oklahoma. Short grasses predominate, but rabbitbrush and mesquite also occur sporadically. The prairie ecosystem is situated on the Central Lowlands and consists mostly of extensive areas of tall grasses. The desert grasslands is an arid ecosystem in southwest Texas dominated by tobosa grass (Garrison et al. 1977).

The wet grasslands ecosystem consists of wet prairies and marshes found along the Atlantic and Gulf coastlines, and also includes the Everglades and palmetto prairie of southern Florida (Garrison et al. 1977). Well over half of the wet grasslands ecosystem is located in Florida. Louisiana and Texas also contain significant areas of coastal prairies and marsh.

Aside from their importance as a producer of forage for domestic livestock, rangelands of the South offer a multitude of scenic and recreational resources, and are also extremely important for providing unique habitat for several species of threatened and endangered species. The golden-cheeked warbler, Texas red wolf, Attwater's prairie chicken, Florida panther, Florida great white

heron, and Everglades kite are some examples. Several other species of wildlife, such as the collared peccary, coatiundi, and pronghorn antelope, are also unique to the rangelands.

## WATER AREAS

Water areas in the South cover some 2 million acres, 4% of the total area in the region (table 13). Florida and Louisiana have the highest concentrations of water—10% or more of the total area in each of these two states. North Carolina, Texas, and Virginia each contain large areas of water. Inland water makes up more than four-fifths of the South's water total.

The major bodies of inland water include the lower Mississippi River and tributaries, lakes and waterways of the Mississippi delta, large numbers of small and large lakes in Florida, and numerous large water impoundments constructed across the South. Small ponds and streams plus Atlantic and Gulf coastal waters make up the remaining area of water.

The South's water areas provide valuable habitat for fish and wildlife. They are used by migratory birds overwintering and thereby directly affect the wildlife resources of other regions. Water areas ranging from small farm ponds to coastal waters provide important sites for water-based recreation activities. Domestic and industrial consumption of water is also an extremely important use.

Table 13.—Water areas (thousand acres) of the South, by region, and State

Region and state	Total water area	Inland water			Other water <sup>3</sup>
		Total	Large areas <sup>1</sup>	Small areas <sup>2</sup>	
<b>Southeast</b>					
Florida	4,467	3,357	2,887	470	1,110
Georgia	897	866	546	320	31
North Carolina	2,714	2,714	2,480	234	0
South Carolina	909	821	592	229	88
Virginia	1,792	825	681	144	967
Total	10,779	8,583	7,186	1,397	2,196
<b>South Central</b>					
Alabama	1,193	835	633	202	358
Arkansas	914	914	705	209	0
Kentucky	514	514	474	40	0
Louisiana	3,338	2,688	2,354	334	650
Mississippi	1,056	700	345	355	356
Oklahoma	990	990	797	193	0
Tennessee	762	762	649	113	0
Texas	3,792	3,739	2,993	749	53
Total	12,559	11,142	8,950	2,192	1,417
South total	23,338	19,725	16,136	3,589	3,613

<sup>1</sup>Lakes and ponds at least 40 acres in size; waterways 1/8 mile or more in width.

<sup>2</sup>Lakes and ponds between 2 and 40 acres in size; waterways less than 1/8 mile in width.

<sup>3</sup>Atlantic and Gulf Coastal waters.

Source: Forest Service RPA data base, 1987.

## CHAPTER 4: THE ROCKY MOUNTAINS

### LOCATION AND CHARACTERISTICS

The eight States making up the Rocky Mountain Section (Montana, Idaho, Wyoming, Utah, Nevada, Colorado, Arizona, and New Mexico) cover about 863,531 square miles which is roughly 552.7 million acres (fig. 2 and table 1). The land area within these States totals 546.6 million acres, nearly a fourth of the entire Nation.

A variety of land forms provide the scenic landscapes for which the Rocky Mountain States are famous (fig. 18). The plains rolling westward into the eastern extremes of these states give way to the steep glaciated terrain of the Rocky Mountains. These states are also characterized by high elevation interior basins and plateaus, and highly eroded tablelands, particularly in Arizona, Utah, Wyoming, and western Colorado. This section also has extensive areas of arid desert in Arizona and New Mexico.

The dry climate in this section is labeled "semiarid continental", because evaporation usually exceeds precipitation even though maximum rainfall occurs in the summer months. Winters are cold and dry, the summers warm to hot. Winter precipitation is largely in the form of snow and is greater in the mountains than in the more plains-like areas. Moisture is the most limiting factor for plant growth. The principal soil-forming process is calcification with salinization on poorly drained soils. Soils are generally rich in bases and often contain an excess of precipitated calcium carbonate. Except in forested areas, the organic matter content is low, and in many areas the soils are thin and fragile.

### FOREST LAND

More than 138 million acres, roughly 25% of the land area in this section, are occupied by forests, predominantly of softwood species. Almost half the total forest land is in the three States of Colorado, Idaho, and Montana. Although Montana has a slightly larger forest area, Idaho has nearly as much and is the most heavily forested, with more than 41% of its land area taken up by forest land. The percent of total land area that is forested in the eight Rocky Mountain states is as follows:

State	Percent forested
Idaho	41.4
Colorado	32.2
Utah	30.9
Arizona	26.7
New Mexico	23.9
Montana	23.6
Wyoming	16.1
Nevada	12.7

Forest land in the Rocky Mountain states has two components—timberland and woodland. Timberland forests are those whose species traditionally have been used for industrial roundwood products such as veneer and sawlogs, pulpwood, and poles. Woodland forest species have generally not been used for industrial products because of form and stature; wood product uses are generally limited to fenceposts and fuelwood. In past classifications of forest land, woodlands have usually been categorized as unproductive or "other" forest land. In the Rocky Mountain states, woodlands occur as either pinyon-juniper (softwoods) or chaparral-mountain shrub (hardwoods). In terms of area, there is more pinyon-juniper forest than any other type (figure 19). It makes up 34% of the total forest land in the Rocky Mountains (table 14).

A sometimes confusing situation regarding pinyon-juniper and chaparral-mountain shrub lands is that although they are considered forest land, their primary use is grazing, making them major range ecosystems.

The distribution of forest ecosystems and other vegetational zones is largely a function of growth environment (soils, moisture, and temperature), which is affected by latitude, elevation, aspect or slope exposure, and prevailing wind direction. Generally, more similar vegetational zones occur at higher elevations in the south than in the north because of temperature and moisture regimens.



Figure 18.—Land forms and vegetation offer a variety of scenic landscapes in the Rocky Mountain States.



Figure 19.—Pinyon-juniper land is a major forest as well as rangeland ecosystem.

### Ecosystems

Five forest ecosystems totaling some 112 million acres make up about 80% of the forest land in the Rocky Mountain states—pinyon-juniper, Douglas-fir, fir-spruce, ponderosa pine, and lodgepole pine (table 14). All but pinyon-juniper are important for wood products. Other major softwood ecosystems are largely confined to Idaho and Montana. Hardwood species have wide ranges throughout much of the Rocky Mountain States area.

### Timberland

**Ponderosa pine.**—The ponderosa pine ecosystem is found to some extent in all the Rocky Mountain states (fig. 5). It covers about 16.5 million acres, nearly half of which is in Arizona and New Mexico. It is usually the first timberland forest ecosystem encountered above the desert floor and often grows in pure stands, especially in the southwest. In Idaho and Montana, ponderosa pine is often associated with Douglas-fir, larch, and other species requiring more moisture.

**Douglas-fir.**—In the Rocky Mountains, this ecosystem usually occupies elevations immediately above the ponderosa pine zone and below the fir-spruce; however, in some situations the Douglas-fir and ponderosa pine zones are reversed. More than 13 million of the 17.9 million acres of this ecosystem are in Idaho and Montana. Pure stands of Douglas-fir are found where it has developed as a climax forest in northern Colorado, and in parts of Wyoming and Utah. In Montana and northern Idaho where moisture is abundant, Engelmann spruce and western larch are common associates and are often the dominant species in the ecosystem. In terms of timber production, the Douglas-fir ecosystem is second only to ponderosa pine in the Rocky Mountain states.

**Lodgepole pine.**—The lodgepole pine ecosystem typically consists of pure, or nearly pure, and often very dense, stands of the species. There are 14.6 million acres in the Rocky Mountain states, 55% of which is in Idaho and Montana. Most of the rest is in Wyoming and central Colorado. Lodgepole pine stands are frequently replaced through succession by other softwood species such as Douglas-fir, grand fir, and subalpine fir. But it is not uncommon for pure stands of lodgepole pine to take on the appearance of a climax type. Dense stands in this ecosystem usually have no understory vegetation.

**Fir-spruce.**—This ecosystem is found in high elevation areas where temperatures are cool and moisture abundant. Most of its 16 million acres are in the higher latitudes and elevations of Idaho, Montana, Wyoming, Utah, and Colorado. Grand fir, subalpine fir, and Engelmann spruce are the major species. In the northern Rocky Mountains, larch, western redcedar, and western white pine are common associates. In Colorado, Wyoming, and Utah, this ecosystem forms picture postcard landscapes at timberline.

**Others.**—The western white pine, larch, and hemlock ecosystems comprise less than 3% of the total forest land in the Rocky Mountain states and are restricted to Idaho and Montana. The western white pine ecosystem occupies the same general temperature belt as Douglas-fir—moist sites above ponderosa pine and below the fir-spruce. This subclimax type generally has a mixture of western redcedar, western hemlock, grand fir, Douglas-fir, and western larch, with ponderosa pine at lower

Table 14.—Area of forest land (thousand acres) in the Rocky Mountain states by major ecosystem, 1987

State	Total	Douglas-fir	Ponderosa pine	Western white pine	Fir-spruce	Hemlock-Sitka spruce	Larch	Lodgepole pine	Red-wood	Other soft-woods	Western hard-woods	Pinyon-juniper	Chaparral	Non-stocked
Arizona	19,384	263	3,786	0	417	0	0	0	0	840	1,050	12,918	0	111
Colorado	21,338	1,930	2,369	0	4,432	0	0	2,219	0	96	4,239	5,745	0	308
Idaho	21,818	6,586	2,040	226	4,354	1,322	890	3,154	0	1,079	970	513	0	685
Montana	21,910	6,553	2,773	36	2,162	179	927	4,844	0	2,480	481	83	0	1,392
Nevada	8,927	19	78	1	220	3	0	28	0	180	310	7,982	77	31
New Mexico	18,526	1,016	3,401	0	772	0	0	0	0	1,184	897	10,089	0	1,169
Utah	16,233	839	521	0	1,604	0	0	664	0	223	2,914	9,316	12	139
Wyoming	9,966	736	1,544	0	2,178	0	0	3,641	0	297	514	709	0	347
Rocky Mountain Total	138,104	17,942	16,511	263	16,139	1,504	1,817	14,550	0	6,379	11,374	47,354	88	4,182

Note: Data may not add to totals because of rounding.

Source: Forest Service RPA data base, 1987.

elevations, and includes Engelmann spruce at higher elevations.

The larch ecosystem is, for the most part, confined to the area west of the Continental Divide in Montana and north of the Salmon River in Idaho. Western larch is a deciduous conifer that often is perpetuated as a sub-climax species by fire, much the same as lodgepole pine. In some parts of northern Idaho, it is a pioneer species following fire or other severe disturbance. On cooler, more moist sites, it mixes with Douglas-fir and grand fir; on drier sites with ponderosa pine.

The hemlock ecosystem has both western and mountain hemlock as major species. Mountain hemlock is found at high elevations in association with whitebark pine, subalpine fir, and Engelmann spruce up to timberline. At elevations below 6,000 feet, western hemlock is the major associate. In areas where western redcedar is a major associate, the ecosystem may represent a climax forest; where present areas of the ecosystem have established following fires, less shade-tolerant, subclimax species such as white pine and Douglas-fir are retained. About 88% of this ecosystem is in Idaho.

The 11 million acres of hardwoods in the Rocky Mountain States include woodland species such as oak. Timberland hardwoods consist primarily of two species, quaking aspen and cottonwood. In the high country, aspen is usually found as small patches or groups of patches punctuating the mountainsides as landscape decorations. However, in Colorado and Utah where two-thirds of the aspen is located, there are rather extensive areas. Aspen, a relatively short-lived species (up to 120 years), is nearly always replaced by coniferous species, particularly species of spruce and fir, in the normal successional scheme. It is the only hardwood in the Rocky Mountains managed for timber production. At lower elevations, the hardwoods are represented by cottonwood, usually found along streambanks and in the low valleys.

## Woodland

**Pinyon-juniper.**—The pinyon-juniper ecosystem covers some 47 million acres, principally on the dry plateaus and broken tablelands of Arizona, New Mexico, western Colorado, Utah, and Nevada. In Arizona and New Mexico it is the predominant forest type. It is a rather uniform type, with few tree species, generally occupying an elevational zone (4,500 to 7,500 feet) above the desert floor and below ponderosa pine. The species composition changes geographically and can vary from pure pinyon pine to pure juniper.

**Chaparral-mountain shrub.**—In the Rocky Mountain states, this ecosystem is characterized by the presence of oak species and mountain-mahogany (*Cercocarpus* spp.). In the northern areas, gambel oak and other deciduous shrubs are dominant, but give way to evergreen species in Arizona and New Mexico. Included in this ecosystem are large areas of oak-juniper woodlands in the southwest.

Additional information about the vegetation of the pinyon-juniper and chaparral-mountain shrub ecosystems is included below in the rangeland subsection.

## Ownership

In the Rocky Mountain states, three-fourths of the forest land is publicly owned (Green et al. 1983). Federal agencies, principally the Forest Service, administer 94 million acres or two-thirds of the total. In no state is less than half the forest land under federal jurisdiction and several states have much more: Nevada, 86%; Idaho, 77%; Utah, 74%; and Montana, 72%. Except in Nevada and Utah where the Bureau of Land Management has the major holdings, the Forest Service is the chief caretaker, managing over 67 million acres—nearly half of all forest lands.

The timberland area that is not reserved from cutting has generally the same ownership pattern. Roughly 75% is publicly owned; 60% is in national forests. Other public lands are mostly state-owned, with the largest holdings in Idaho and Montana. Much of the state-owned land is in scattered tracts (two sections per township), as a result of the original disposition of federal lands through grants in the 1800s. Isolation and tract size often cause problems in administration and management of such lands. Most of the 3 million acres of industry-owned timberland is in Montana and Idaho; most privately owned nonindustrial land is in Idaho, Montana, Colorado, and New Mexico.

## Productivity

Based on the capacity of the land to produce wood fiber, the productivity of forest land in the Rocky Mountain states is low compared to other major timber-producing areas in the United States. Scant precipitation and thin soils over much of the area, and short growing seasons at higher elevations, are major factors. About half the forest land cannot produce 20 cubic feet of wood per acre per year, the standard below which forest land is considered unproductive. For the most part, these are the pinyon-juniper woodlands.

Even the timberlands are low on the productivity scale. Over half of the timberland cannot produce 50 cubic feet per acre per year, and only 11 million acres are highly productive and can produce more than 85 cubic feet per acre per year.

Most of these highly productive lands are in Idaho and Montana, and roughly 75% is in national forests. There is some variation in productivity among ecosystems mainly attributable to soil/moisture relationships characteristic of the sites on which trees grow. The most productive sites are generally occupied by the hemlock-cedar, Douglas-fir, and fir-spruce forest types.

At the other end of the scale are the pinyon-juniper woodlands. The very nature of this ecosystem and the climatic conditions where it occurs, preclude any substantial growth rates. However, the 47 million acres of this ecosystem have high value for a variety of resource uses.

## Use

The use of forest land in the Rocky Mountain states is moving away from a preoccupation with timber toward less consumptive uses associated with other resource

values. For example, recreation/tourism is a big and growing business in the Rockies. The attraction is an almost endless array of forest landscapes whose environments include a variety of wildlife, water, and other resources and values. Because three-fourths of the forest lands in the Rocky Mountain states are publicly owned, the use and management of these lands depend on what the people want from them.

The future use of the forests will be dictated largely by public land-use policies that reflect public goals. Any single use emphasis at local levels will continue to be given a lot of emotional and scientific (if not judicial) attention. The principal concern of the public is whether prospective supplies of all outputs from the forest are able to meet increasing demands while maintaining the integrity of the land base and enhancing the environment.

### Trends In Forest Area

Lack of early historical data makes tracking trends in forest areas in the Rocky Mountain states difficult. Some land was cleared for settlement, and forests were exploited to fulfill the needs of economic and territorial expansion—railroad ties, mine timbers, and charcoal for ore reduction. However, most of the cutover areas have reverted back to forest.

In recent decades, there has been a modest, but steady, decline in the nonreserved forest land base throughout the section. Substantial areas of privately owned forest land have been subdivided for homesites, particularly in Montana, Idaho, and Colorado, and some public lands have been included in the National Wilderness Preservation System or set aside for other special uses.

Future prospects are for the forest land acreage to remain fairly stable. However, allocation of forest land for various uses likely will change. Clearing for roads, urban development, power transmission rights-of-way, and surface mining will surely continue. Both productive and relatively unproductive land will be affected, but the extent of change is unknown. Although there will be declines in the areas used to produce timber, most other resource uses and values should be available and maintained.

## RANGELANDS

### Ecosystems

The rangeland ecosystems of the Rocky Mountain states are extremely diverse due to great variation in climate, precipitation, and elevation. These ecosystems make up almost one-half of the Nation's rangelands, and include woodland, shrubland, and grassland. Two forest ecosystems described in the woodland section, pinyon-juniper and chaparral-mountain shrub, are included in the rangeland section because their predominant use has traditionally been as range. Woodland can be characterized as unproductive forest land, which is incapable of

producing annually 20 cubic feet per acre of industrial wood under natural conditions because of such adverse site conditions as sterile soils, dry climate, poor drainage, high elevation, and steepness or rockiness. The total rangeland area, including these woodlands, is about 336 million acres, or 61% of the total land base of this section (table 1).

The classification scheme used for describing the major rangeland ecosystems of the Rocky Mountains is that of Garrison et al. (1977). Other sources of information include Branson (1985), Stoddart et al. (1975), and USDA Forest Service (1981).

### Woodland

**Pinyon-juniper.**—The pinyon-juniper type is often composed of a mix of both species, but juniper species occupy by far the most acreage. The area of the western United States covered by pinyon-juniper forests is currently estimated at more than 47 million acres (table 14). The most extensive stands occur in Nevada, Utah, Arizona, New Mexico, and Colorado, with additional occurrence in Idaho and Wyoming. Species of pinyon pine include common, singleleaf, and Mexican. Junipers include oneseed, Utah, Rocky Mountain, and alligator. Associated species include mountain-mahogany, cliffrose, bluebunch wheatgrass, blue grama, galleta, Indian ricegrass, sideoats grama, needlegrasses, and muhlys.

Annual precipitation on these lands is from 12 to 18 inches, and soils are relatively coarse. Densities vary from scattered trees in grasslands to dense stands with little or no understory. This type is usually found between 4,500 and 7,500 feet elevation.

In the past, the pinyon-juniper forests have been removed by chaining and burned to increase forage production for livestock. However, in the last decade, the value and importance of pinyon-juniper wood for fuel, and of pinyon-juniper forests for wildlife habitat, recreation, and commercial harvest of pinyon nuts have gained increasing recognition.

**Chaparral-mountain shrub.**—Intermingled with and below the pinyon-juniper lies the chaparral-mountain shrub type; a sort of discontinuous foothill transition zone between coniferous forest and grass or shrublands. The term chaparral refers to dense stands of evergreen and shrubby vegetation, and is represented in the Rocky Mountains mainly in Arizona by scrub live oak. Other scrub oak types, not strictly chaparral, occupy vast areas in the West, especially in the southwest. These include evergreen and deciduous oaks such as gambel, wavyleaf, emory, and gray. Mountain shrub species include maple, mountain-mahogany, serviceberry, chokecherry, and buckbrush.

The chaparral and oak types are usually composed of close-growing species, forming dense stands with low grazing potential. The mountain shrub areas are usually more open, with considerable grass and forb understory. Both ecosystems are typified by rough topography and low-to-moderate precipitation (10 to 28 inches annually). These types cover about 8 million acres in the Rocky Mountain States (USDA Forest Service 1981).

## Shrubland

**Sagebrush.**—The sagebrush type is the second largest range ecosystem in the United States with roughly 105 million acres, most of which occurs in the Rocky Mountains.

This broad, cold-desert ecosystem occupies vast plains and plateaus in Idaho, Nevada, Oregon and Wyoming, and is found in all the other Rocky Mountain States. Big sagebrush, the dominant species, occurs on a variety of wet and dry sites as well as strongly alkaline and nonalkaline soils. Different varieties and species occur at elevations from 5,000 to 10,000 feet and receive from 6 to 20 inches of annual precipitation.

Other species are black, low, and silver sagebrush, associated with wheatgrasses, fescues, bluegrasses, and bromes. Most of the land within this type is used for sheep and cattle grazing, mostly in the spring and fall. Some of the land in this type will support irrigated ranching if enough water is available. Antelope use the sagebrush zone for habitat year-round, and it can be important for deer winter range.

**Southwestern shrubsteppe.**—Throughout southern Arizona, New Mexico and Texas, the southwestern shrubsteppe occupies roughly 27 million acres of nearly level desert plains. Much of this area was once primarily grassland, but has been modified into shrubland through livestock grazing. *Yucca* is one of the most characteristic woody plants, along with mesquite, tarrubush, and creosote bush. Black grama, three-awns, tobosa, and sideoats grama are commonly occurring grasses. Cover ranges from predominantly shrubs with occasional grass to nearly all grass. Annual precipitation is as low as 10 inches in the west to 18 inches in the east. Elevationally, this type occurs below the pinyon-juniper.

**Desert shrub.**—An arid climate, poorly developed soils, and sparse vegetation characterize the desert shrub ecosystem. It includes the salt-desert shrub type of the cold desert. This type occurs below 5,500 feet in the Great Basin and includes shrubs that are salt-tolerant, such as saltbush, greasewood, and pickleweed.

This ecosystem also includes the hot-desert mesquite bosques and cactus-shrub communities of the southwest. These communities include mesquite, bursage, creosote bush, palo verde, pricklypear, cholla, saguaro, and several desert grasses.

Precipitation throughout the ecosystem is very low (5 to 10 inches annually). The salt-desert shrub type is used mainly for winter range for sheep. The mesquite bosques have high forage production potential, especially when the mesquite cover is reduced. This ecosystem covers about 58 million acres.

## Grassland

Grasslands represent some of the most productive rangelands of the world, yet their range value is being diminished through cultivation, heavy grazing, and shrub encroachment. Woody vegetation is favored by grazing and control of fire.

**Mountain grasslands.**—Ecologically, grasslands occur between the wetter forests and the drier desert shrublands. The mountain grassland ecosystem covers about 17 million acres and is characterized by bunchgrasses. This ecosystem consists mainly of open, untimbered areas, yet may interface with ponderosa pine, Douglas-fir, lodgepole pine, or even spruce-fir forests at high elevation. This type also sometimes borders the sagebrush zone in the foothills. Annual precipitation is about 20 inches; it can be as much as 30 inches at the higher elevations.

Bluebunch wheatgrass, Idaho fescue, needle-and-thread grass, Sandberg bluegrass, and junegrass are the common grasses of this ecosystem. Desirable forbs may be abundant. Wildrye is a grass common to the bottomlands. Where native grass cover has been removed, cheatgrass usually invades.

Low elevation land that has not been cultivated is valuable spring and fall range for livestock, and may also be critical winter range for big game. At high elevations, this type is prime summer range for livestock and big game. This ecosystem includes many prime watershed and recreation lands.

**Mountain meadows.**—This ecosystem usually occurs in wet or moist valleys and basin-like areas in the forest zones of the Rocky Mountains. The plant community is usually composed of hairgrasses, bluegrasses, sedges, rushes, and some water-loving shrubs such as willow. These scattered areas comprise a small part of the rangeland in the West—only 2 million acres.

These areas are sensitive to abuse, and many small meadows have been destroyed (or severely damaged) through road and trail building and overuse by livestock or campers. Some meadows within large expanses of forest land are critical for wildlife use by both big game and waterfowl. These meadows also provide good grazing for livestock.

**Desert grasslands.**—In close proximity to the southwestern shrubsteppe type in the southwestern states, the desert grasslands occupy roughly 22 million acres. These grasslands occur at elevations less than 4,200 feet, and are the driest of the grasslands, receiving only 8 to 15 inches of annual precipitation. The single most important grass species is black grama, with curlymesquite, three-awns, blue grama, tobosa, and galleta as additional members of the plant communities. Shrub cover increases at the lower and higher elevations of this zone. Shrub cover includes mesquite, yucca, creosote bush, and pricklypear.

**Plains grassland.**—The grasslands to the east of the Rocky Mountains probably developed as a result of the rain shadow caused by the mountains, which along with fire eliminated forest from all but the lowlands. The most productive parts of these grasslands have been converted to cropland.

The plains grassland ecosystem is often called the short- or mixed-grass prairie; it forms a continuous zone into New Mexico in the South and to mid-Nebraska, Kansas, and the Dakotas on the east. This is the largest rangeland ecosystem in the United States. In the Rocky Mountain states, this type covers about 87 million acres.

Precipitation increases eastward from about 12 inches to 20. The predominant grasses are blue grama and buffalo grass. These short, warm-season grasses are remarkably resistant to damage from grazing, but under heavy use may give way to weedy shrubs such as snake-weed and pricklypear.

### Ownership

About 167.4 million acres (50%) of the rangeland in the Rocky Mountain states is in public ownership, mostly in the care of federal agencies:

Owner group	Thousand Acres	Percent of total
Forest Service	33,482	10
Bureau of Land Management	125,558	38
Other Federal	8,371	2
Total Federal	167,411	50
Non Federal	168,407	50
TOTAL	335,818	100

In Nevada, federal agencies administer 92% of all rangelands.

### Productivity

Productivity of the rangeland ecosystems in the Rocky Mountain states is highly variable. The woodlands may produce from 0 to 2,000 pounds of herbage per acre annually, with the chaparral-mountain shrub type averaging from 1,000 to 2,000 pounds per acre. Shrublands have a similar range of productivity, with sagebrush having the highest. In desert grasslands, herbage production is never much greater than 1,000 pounds per acre. The other extreme is the mountain meadow type, which may produce as much as 4,000 pounds of herbage per acre. The shortgrass plains type averages under 2,000 pounds per acre, with mountain grasslands nearer 3,000. As a rule of thumb, 30 to 40% of herbage can be utilized as forage (Garrison et al. 1977).

### Use

One of the dominant uses of all these lands has traditionally been livestock grazing. Some of these lands are well suited for grazing, but others have been irreversibly changed by it, due to decrease in plant cover and soil loss. Other uses of rangeland are for watersheds, wildlife habitat, timber, and recreation. Rangelands also have less tangible values such as esthetics and clean air. Some of what was originally rangeland is now under cultivation or development. Any management and use of rangelands should involve balancing the various

ecological components—soil, vegetation, water, animals, climate, fire, and topography—to maintain the stability of the ecosystems.

### Trends In Rangeland Area

The range of pinyon-juniper is thought to have increased since European settlement due to over-grazing, fire suppression, and climatic changes, but no real data are available, however, on the extent of the changes.

The most productive areas of the grasslands and sagebrush types have already been converted to cropland. Where it is still economically feasible, mechanical or chemical means are used to remove woody vegetation such as sagebrush, pinyon-juniper, or mesquite to increase grass cover for livestock forage. A much more widespread trend is that of shrub encroachment on native grasslands, which is caused by poor grazing management and control of fire.

### WATER AREAS

It is no surprise that the Rocky Mountain Section is the driest in the country in terms of rainfall. Water is indeed at a premium. The section has the smallest water area—in both absolute and relative terms—of all the sections.

The total water area (all is inland water) is only about 6.0 million acres (table 1), a mere 1% of the total geographic area of the section, and only about 10% of all the inland water in the United States. More simply stated, these eight states have about a fourth of the total land area and a tenth of the inland water in the country.

Over half (55%) of the Rocky Mountain states' water is in Utah and Montana. Utah alone has 32% of the section's water. Unfortunately, much of it is in (or ends up in) the Great Salt Lake, where it has very limited value.

In addition to the Great Salt Lake, water areas include the upper Missouri (Montana), the Snake (Idaho), and the Colorado (Colorado, Utah, and Arizona) river systems. These major river systems, and others less widely known, have both large impoundments and smaller storage reservoirs. In addition, this mountainous section of the country is laced with many smaller streams and dotted with thousands of lakes, although such waters are minimal in Arizona and Nevada.

Although the amount of inland water in the Rocky Mountain states is relatively small, it is of great importance to the Nation as well as the section. It supports large fish and wildlife populations and is the focal point for many outdoor recreation activities for several million people. But more importantly, the Rocky Mountain States provide much of the water for domestic use and irrigation of the cropland from the Mississippi River through the arid southwest and on into southern California.

## CHAPTER 5: THE PACIFIC COAST

### LOCATION AND CHARACTERISTICS

The Pacific Coast Section includes the four mainland states of Alaska, California, Oregon, and Washington; and the island state of Hawaii. With a land area of 570 million acres, these five states contain one-fourth of the total area in the Nation.

The latitudinal span of the mainland states is 38 degrees—71 degrees north at Point Barrow, Alaska to 33 degrees north at the southern border of California. The Hawaiian Islands, stretching from 28 degrees north to 18 degrees north, bring the total reach of the Pacific States up to 53 degrees of latitude, from north of the arctic circle to the tropics. The extremes of environmental conditions attributable to latitudinal spread in this vast region are moderated in many areas, and exaggerated in others, by the influences of ocean currents, prevailing winds, and land form. In the mainland states are four major climatic zones — arctic, maritime, continental, and mediterranean (Bailey 1978).

In the arctic zone of Alaska's northern and western coastal plains precipitation is minimal (10 inches per year or less), surface winds are strong and frequent, and permafrost is extensive in the wet tundra soils. In most of this area forests are absent, or reduced to shrub thickets.

The maritime climatic zone extends from the south-central coast of Alaska to the central coast of California. This zone is characterized by mild, wet winters, and relatively cool, humid summers. Annual precipitation ranges from more than 150 inches in places in coastal Alaska and western Washington to less than 30 inches in some of the "rain shadow" valleys between the Coast Range and Cascades in Oregon and Washington. In Alaska and California the maritime zone is a narrow band along the coast, with steep mountains, deep canyons, and little flat ground in coastal plains or valleys. In Oregon and Washington the maritime zone encompasses most of the area west of the crest of the Cascade Range. Some of the most productive forest soils in the world are found in this area; but soils of very low productivity can also be found — on steep slopes and ridgetops, in poorly drained areas, on peridotite and serpentine rock, and on geologically recent lava flows.

In the maritime zone are some of the tallest trees in the world, and the most productive coniferous forests in the northern hemisphere. The redwood belt of California, the spruce and hemlock forests of coastal Alaska, and the Pacific Northwest Region west of the Cascade Mountains in Oregon and Washington are within the maritime zone.

The continental climatic zone includes Alaska's interior, where subarctic conditions occur, and the warmer inland region east of the Cascade and Sierra

Nevada Mountains in Washington, Oregon and California. Winter and summer temperatures in Alaska's interior vary up to 100 °F, precipitation is low, and permafrost is common. Forests are much less productive here than in Alaska's coastal belt. The inland area of Oregon, Washington, and California is similar to the Rocky Mountain Section, with forested mountains and plateaus rising above sagebrush steppe and grassland. Precipitation ranges from less than 10 inches in arid valleys to more than 60 inches in some mountainous areas. Forests of inland Oregon, Washington, and California are less productive, on the average, than those in the maritime zone. The better sites, however, are quite productive, yielding high quality ponderosa pine, western larch, true fir, and inland Douglas-fir.

The mediterranean climatic zone includes most of California (that east and south of the maritime strip, and west of the continental zone). Winters are mild and moist, and summers are extremely hot and dry. Extremely variable topography and complex geology within this zone produce areas of treeless grasslands, extensive shrublands, oak savannas, dense hardwood forests, and coniferous forests, some as tall and productive as those in the maritime zone.

The Hawaiian Islands, though tropical by location, enjoy the cooling effect of the northeast trade winds. Temperatures at most locations in Hawaii's lowlands vary relatively little over the year—from a record maximum of 88 °F, and a record minimum of 57 °F with a mean annual temperature of 75 °F at Honolulu. Temperatures vary greatly by elevation, and windward locations tend to be cooler than leeward ones. Precipitation is highly variable from place to place, ranging from about 7 inches on the leeward coast of Hawaii to about 480 inches at Mount Waialeale on Kauai. The soils in the Hawaiian Islands, developed from volcanic ash and basaltic lava under a wide range of conditions, produce some of the most varied flora in the world.

### FOREST LAND

Forests cover 220 million acres, or 39%, of the land area in the Pacific Coast States (table 1). This amounts to 30% of the total forest area in the Nation. Productive timberland, both reserved and available, totals about 85 million acres. Productive timberland is capable of growing 20 or more cubic feet of industrial wood per acre per year on a continuous basis. Other forest land totals 135 million acres. Included are pinyon-juniper woodland, hardwood savanna, chaparral, and extensive areas of coniferous timber species on land incapable of growing 20 cubic feet of industrial wood per acre per year, or on land that cannot be managed for timber on a continuous

basis because of steepness, rockiness, poor drainage, or other environmental factors.

### Ecosystems

In this discussion the term "ecosystem" is synonymous with the term "forest type." Forest types were classified during recent extensive forest inventories according to the predominant tree species, whether or not they formed "climax" types or were of economic value. Because of the large number of species types, it was necessary to group specific types into broader type categories. Also, some local type names have been renamed. For example, about 8 million acres of forests in California are classified locally as mixed conifer type, often containing five or more tree species in varying proportions. Ponderosa pine is almost always present in these stands, and frequently predominates. In this discussion the California mixed conifer type is grouped with ponderosa pine type.

**Douglas-fir.**—This type covers about 21 million acres of forest land. It is the most important forest type, in terms of timber production, in the Pacific Coast Section. The best sites are capable of yielding more than 200 cubic feet per acre per year. Forty-two percent of the type is capable of producing more than 120 cubic feet.

Douglas-fir is the major type in western Oregon and western Washington, where it occupies nearly 60% of the forest area. It is found in the Cascade Mountains from midslopes in the north and mid-to-upper slopes in the south, in the central lowlands, and throughout the Coast Range, as well as in northwestern California, where it covers about 1.1 million acres. Included in the 21 million acres of Douglas-fir type are 4 million acres scattered through the ponderosa pine ecosystem in eastern Oregon and eastern Washington.

The Douglas-fir type is actually a collection of many different plant communities. The most common coniferous tree species associated with Douglas-fir are western hemlock and western redcedar. Others include Pacific silver fir, noble fir, grand fir, Sitka spruce, Port Orford cedar, Alaska cedar, incense-cedar, western larch, western white pine, sugar pine, and ponderosa pine. Hardwoods such as red alder, bigleaf maple, black cottonwood, Oregon white oak and Pacific madrone are also common associates of Douglas-fir.

**Hemlock-Sitka spruce.**—About 16 million acres of this ecosystem is covered by hemlock-Sitka spruce—11 million acres in coastal Alaska, 5 million in Oregon and Washington; fewer than 50,000 acres are in north-coastal California. Four major local types are included in this type: western hemlock, Sitka spruce, western redcedar, and mountain hemlock-subalpine fir. In Alaska, the four local types intermingle and Alaska-cedar becomes an important component. In Oregon and Washington Sitka spruce occurs only in the narrow coastal fog belt and amounts to less than 300,000 acres of the 5 million acres in the hemlock-Sitka spruce type there.

Stands of Sitka spruce on deep soil are among the most productive coniferous forests in the world, yielding as

much as 400 cubic feet of wood per acre per year. Western hemlock on the best sites is capable of yielding 250 cubic feet per acre. However, the average productivity of the hemlock-Sitka spruce type group is somewhat less than that of Douglas-fir, with 36% capable of producing 120 or more cubic feet (42% of the Douglas-fir type can produce 120 or more).

Hemlock-Sitka spruce type tolerates a narrower range of environmental conditions than Douglas-fir, and for that reason the list of associated tree species is somewhat shorter. In Alaska, associated conifer species found in the type include primarily western hemlock, mountain hemlock, western redcedar, Alaska-cedar, Sitka spruce, and lodgepole pine. Many coastal forest stands often contain only two or three tree species. In the mountains away from the coast in Oregon and Washington stands generally are more diverse. Hardwoods are occasionally found in the hemlock-Sitka spruce type, often as pioneer species on disturbed sites.

**Redwood.**—The redwood ecosystem covers about 1.2 million acres. Six thousand acres are in southwestern Oregon and the rest is in California. Redwood is restricted to the narrow summer-fog belt near the Pacific Ocean.

Redwood is the most productive coniferous forest type in the U.S. and probably in the world. The best sites yield more than 400 cubic feet of wood per acre per year. Eighty-nine percent of the redwood type is capable of producing 120 or more cubic feet, and 97% can produce at least 85 cubic feet. Unlike most conifers, redwood can sprout from stumps or roots of cut trees, and several sprouts often originate from one stump. The rapid early growth and high density of young redwood stands on logged over land are attributable to redwood's ability to resprout when cut.

Despite the restrictive environmental requirements of redwood, quite a large number of tree species grow with it. Associated conifers may include grand fir, western hemlock, Sitka spruce, western redcedar, Port Orford cedar, Douglas-fir, Bishop pine, Monterey pine, knobcone pine, shore pine, Pacific yew, California nutmeg, and two species of cypress. Hardwoods include tanoak, Pacific madrone, bigleaf maple, California-laurel, California buckeye, cascara, two species of deciduous oak, and three species of live oak.

**Fir-spruce.**—This is the most extensive forest type in the Pacific Coast Section. In Alaska, the fir-spruce type (which contains no true fir species), is usually associated with hardwoods, or follows hardwoods in ecological succession. The fir-spruce/hardwood forests cover 116 million acres (white spruce and black spruce total 94 million; hardwoods total 22 million). Almost all of this is in Alaska's interior. About 14 million acres are classified as productive timberland, although none produces over 180 cubic feet per acre per year. The remaining 102 million acres of fir-spruce/hardwood type in Alaska are classified as "woodland," forest on sites incapable of growing 20 cubic feet of wood per acre per year because of harsh climate, permafrost, shallow or poorly drained soil, or other environmental factors. Three major ecosystems comprise Alaska's fir-spruce/hardwood type:

bottomland spruce/poplar, upland spruce/hardwood and lowland spruce/hardwood.

In Oregon, Washington, and California, fir-spruce type covers 12 million acres, most of which is productive timberland. In Oregon and Washington the type consists of stands in which the following species, singly or in combination, predominate: white fir, grand fir, subalpine fir, Pacific silver fir, noble fir, Shasta red fir, Engelmann spruce, and Brewer spruce (found only in one county). In California the type consists primarily of white fir, grand fir, California red fir, and Shasta red fir.

In Oregon and Washington the fir-spruce type is found at higher elevations in the moist Cascades and Coast Range Mountains, and in the drier inland mountains. Growing conditions in these settings are somewhat harsher than for neighboring forest types. Only 8% of the type in Oregon and Washington is capable of producing 120 or more cubic feet of wood per acre per year, and 21% is capable of growing 85 or more. Quite a different situation exists in California where 26% of the true fir type is capable of growing 120 or more cubic feet, and 48% can grow at least 85 cubic feet.

**Ponderosa pine.**—About 14 million acres are covered by this ecosystem, of which 12.5 million acres are productive timberland. Included are the ponderosa pine stands of eastern Oregon and eastern Washington; ponderosa and Jeffrey pine stands of southwestern Oregon and California; and the California mixed conifer type, which consists of ponderosa pine and/or Jeffrey pine, sugar pine, white fir, incense-cedar, Douglas-fir, California black oak, and occasionally other hardwoods. Among the other species associated with ponderosa pine in Washington and Oregon are grand fir, western larch, western white pine, lodgepole pine, Engelmann spruce, Oregon white oak, and western juniper. In California, Coulter pine, knobcone pine, Digger pine, western juniper, cypress, canyon live oak, Oregon white oak, and several other hardwoods can be found.

The very best ponderosa pine sites can yield well over 200 cubic feet of wood per acre per year, but 77% of the pine sites are not capable of producing more than 85. Only 10% can yield more than 120 cubic feet. The three major pines in this type—ponderosa, Jeffrey, and sugar—are long-lived species that grow to large size.

Unproductive ponderosa pine “woodland” covers about 1.5 million acres. Included are pine stands in arid forest fringe areas, on lava flows and other rocky sites, and on soils derived from serpentine and peridotite rock. In such areas, forest stands are sparse and trees are short and poorly formed.

**Lodgepole pine.**—This ecosystem, including both the coastal “shore pine” and the inland or mountain form, covers about 3.6 million acres in the Pacific Coast states, where it ranges from southeastern Alaska to southern California. The inland or mountain form is by far the most extensive. It is found in the mountains of the drier interior of Oregon, Washington, and California, and on the pumice flats of central Oregon. Associated species over this range include many conifers and several hardwoods, although pure stands are fairly common.

Lodgepole pine stands in the Pacific Coast states tend to be less productive on the average than lodgepole in

the Rocky Mountains. Only 7% of the type is capable of producing 85 or more cubic feet of wood per acre per year (compared with 14% in the Rockies).

**Miscellaneous conifers.**—Several other forest types with limited area are found in the Pacific Coast states: western white pine, western larch, subalpine larch, Coulter pine, Bishop pine, Monterey pine, Torrey pine, knobcone pine, Digger pine, foxtail pine, bristlecone pine, limber pine, whitebark pine, Pacific yew, several species of cypress, and others. Collectively, they cover about 6.2 million acres. Some of these types are quite productive, and/or are important locally, for many purposes. Two species have been planted extensively in other parts of the world—Monterey pine as a timber species, and Monterey cypress as an ornamental and coastal zone windbreak species.

## Mainland Hardwoods

Mainland hardwoods, excluding those in Alaska's interior forests, cover 14.1 million acres. About 6.4 million acres are productive timberland. In southeast Alaska, red alder and black cottonwood stands are common along streams, but are not extensive. In Oregon and Washington red alder is the most extensive hardwood type. Other types there include bigleaf maple, black cottonwood, Pacific madrone, Oregon white oak, and, in southwestern Oregon, tanoak. In California, tanoak is the major hardwood type on productive forest land, followed by California black oak and several minor hardwoods. Except for those in bottomlands and narrow riparian strips, most of the hardwood stands occupy sites where conifers grew in the past. Logging, fires, and other disturbance have allowed hardwood species to invade or expand on these sites.

In western Washington and northwestern Oregon hardwoods are often found on the very best conifer sites; on most of these sites, the productivity would be greater for conifers. In some cases, however, short-term hardwood yields may be higher than potential conifer yields. About 56% of the hardwood types are on sites capable of yielding 120 or more cubic feet of wood per year, and 77% can produce at least 85.

Unproductive hardwood “woodland” types cover 7.7 million acres, most of which is in California. Unlike the hardwood types on productive timberland, the woodland hardwoods are usually climax types. They occupy the transition zone between conifer forests at higher elevations and treeless grasslands at lower elevations. Most of this area is referred to as “oak woodland,” or “oak savanna,” because oak species predominate. In Washington and northern Oregon, the oak is Oregon white oak. In southern Oregon, California black oak, canyon live oak, and several other hardwoods appear. Oregon white oak is common in northern California. Blue oak is the most extensive type statewide (amounting to nearly 3 million acres). Other oak types in California include coast live oak, canyon live oak, interior live oak, valley oak, California black oak, and Engelmann oak.

Productivity and stand dynamics in Pacific Coast oak woodlands are not well understood. Oaks are not regenerating in many areas; but the reasons are not clear. So although stand volumes of 2,500 to 4,000 cubic feet per acre are fairly common, without information on how long (or what) it takes to establish new stands, potential yields in these types cannot be determined.

**Pinyon-juniper.**—This ecosystem covers about 5 million acres, including 2.5 million in eastern Oregon, and 2.5 million in California. The pinyon-juniper type in the Pacific Coast states represents the western edge of the extensive pinyon-juniper ecosystem of the semi-arid West. Appearing and disappearing as topography dictates, pinyon-juniper types cover about 50 million acres. In Washington, although pinyon-juniper is absent as a type, scattered Rocky Mountain juniper and western juniper trees can be found. Western juniper type is extensive in eastern Oregon where Rocky Mountain juniper trees also occur in a very few locations. In California, the western juniper type occurs east of the Cascades and Sierra Nevada Mountains in the north, merging with Utah juniper and singleleaf pinyon along the Nevada border. California juniper occurs in southern California, and in scattered locations to the north.

The California total wood volume in trees 3 inches and larger in diameter at root crown averages 580 cubic feet per acre in pinyon-juniper stands, and 325 cubic feet per acre in western juniper stands. Mean annual increment over the life of the average stand ranges from 5 to 10 cubic feet per acre. Western juniper trees are typically straight and single-stemmed, and often reach heights of 40 feet or more. Other species of juniper, and pinyon pine tend to be shorter, crooked, and multi-stemmed. Therefore, western juniper stands, though producing less total wood volume than pinyon-juniper, produce more volume of industrial wood (in straight logs at least 8 feet long to a 4-inch top). Western juniper stands average 170 cubic feet of industrial wood per acre compared with 103 cubic feet for pinyon-juniper.

The durability of juniper wood makes it desirable for fence posts. The average number of fence posts that could be cut from an acre of western juniper is about 110, compared with only 10 from pinyon-juniper stands.

**Chaparral.**—Chaparral covers 7.6 million acres in the Pacific Coast states, most of which is within the mediterranean climatic zone in California. Chaparral type is made up of several species of large shrubs or dwarf trees which are well adapted to survive the long dry summers, periodic torrential storms, and recurring wildfires common in its range. Common species include chamise, manzanita, ceanothus, mountain-mahogany, sumac, buckthorn, toyon, silktassel, California buckeye, and several species of shrubby oaks.

Chaparral stands are typically very dense and range from 3 to 15 feet high. Biomass productivity of chaparral varies by type. Annual increments of total above-ground woody biomass of .25 to .50 tons per acre have been measured in chamise stands; .5 to 1.8 tons in ceanothus stands; .25 to 1.25 tons in scrub oak. Many chaparral sites can be successfully converted to productive grass land, but without careful maintenance, most

of these conversions eventually revert to chaparral (Conrad and Oechel 1982, Wakimoto and Menke 1978).

## Hawaiian Islands

The Hawaiian Island ecosystems are diverse and can be classified according to whether they occur on the dry, leeward side of an island, or the wet, windward side; and their elevational position. The vegetation of the leeward lowlands consists mostly of introduced plants in a grassland or savanna setting, such as kiawe (mesquite) and haole koa (leucaena). Above the lowlands on the leeward side are evergreen scrub and forest, consisting mostly of exotic trees or tree-like shrubs such as guava, Java plum, and Christmasberry. On the windward side of the islands evergreen rain forests predominate, characterized by ohia and koa, both native. They account for more than 800,000 acres of the 1.7 million acres of forest land in the State. Ohio is the most abundant. On Maui and Hawaii, the two highest islands, rain forests are replaced at about 6,000 feet by mountain parkland and savanna. Koa and mamane, both native legumes, are prominent trees in this zone. Above the parkland and savanna is the alpine scrub, and finally, alpine tundra on the highest peaks (Buck, 1987).

The productivity of Hawaii's forests is variable. Forests on recent lava flows are relatively unproductive. Productivity of deep soil forest sites is very high.

Greatest yields measured are in plantations of exotics such as eucalyptus, where annual height growth as great as 10 feet has been measured.

## Ownership, Uses, and Trends in Forest Area

Of the 220 million acres of forest land in the 5-state area, 72 million acres are privately owned. Of the 145 million acres in public ownership, 46 million are in national forests; the remaining 99 million acres are held by various public agencies, including state, county, municipal, and other federal agencies (Bureau of Land Management, Department of Defense, National Park Service, Bureau of Indian Affairs, and others). Percentage distribution by owner group is: private, 33%; national forests, 21%; other public, 46%.

Forests in the Pacific Coast states, like those elsewhere, are used for many purposes. To some degree all categories of forest use occur in all states. The particular mix of forest uses depends on ecosystem, ownership, institutional constraints, economics, and the wishes of society. A discussion of ownership, use, and trends by individual Pacific Coast states follows.

## Alaska

Distribution of forest land in public and private ownership has changed dramatically in the past decade as a result of three national legislative acts—the Alaska Statehood Act of 1958, the Alaska Native Claims Settlement

Act of 1971, and the Alaska National Interest Lands Conservation Act. Previously, almost 95% of the forest in Alaska was administered by the federal agencies. The Forest Service administered about 11 million acres in the southeastern coastal area; the Bureau of Land Management (BLM) administered ten times that area, including most of the state's interior. Much of the land formerly administered by the BLM is now distributed among private individuals, Alaska Native corporations, and state agencies. The final disposition is yet to be made on some lands being considered for ownership transaction. Private ownership currently represents 38% of Alaska's forest land; the state owns 32%; and 30% is federally owned.

The sector of Alaska's economy based on timber is relatively small, despite the vast forest area. In perspective, it ranks with tourism, behind oil and fisheries. Large-scale forest commodity production is limited to coastal, southeastern Alaska where the productive Sitka spruce-hemlock forests provide resources for sawn products, chips and pulp. Relatively little industrial use is made of interior forests because of their low productivity, relative inaccessibility, and great distance from processing facilities and markets. Fuelwood, lumber, and sided houselogs produced by part-time mills for local use, are the major wood products of the interior. A few cabinet-makers use the local birch and cottonwood in their trade.

While vast changes have occurred in Alaska's forest ownership pattern, the bulk of the highly productive coastal forests remains in national forests. They have provided most of the wood used in mills in that area for several decades. (By law, all timber harvested from federal lands in Alaska must be processed initially in Alaska before it can be exported). In the past ten years a substantial area of national forest land has been reserved as wilderness areas, which currently amount to about 1.6 million acres. This leaves 4.5 million acres of productive timberland available for resource management in national forests in the coastal area. While researchers have provided guidelines and techniques for managing Alaska's coastal forests for timber production, and fish and wildlife habitat protection and enhancement, controversy has heightened over the disposition of many areas outside wilderness boundaries. Disagreements have also arisen over how areas dedicated to resource production are to be managed—what logging method, what size cutting unit, what rotation length, what species to feature, whether or not to salvage dead trees, etc. Past trends would suggest that a smaller area of national forest land will be available for timber production in the future, but it will be more productive. Whether or not the reduced area of forest managed for timber production can supply as much wood as is now being harvested in old growth stands is uncertain.

The increase in privately owned forest in Alaska is expected to affect trends in use. Included are 694,000 acres of productive coastal timberland and 5.5 million acres of productive forest in the interior. Timber harvested from these lands is now exempt from the law requiring primary processing in Alaska. This could affect

local economies and the price of stumpage. It could also have long-term effects on resource allocation and protection.

## California

California is rich in renewable resources and has the second greatest area of forest in the Nation, with 39.4 million acres. The state has a long history of industrial use of its forests; for several decades it has ranked among the top four states in the Nation in production of softwood commodities. California is now the scene of a kind of civil war between those who depend on traditional resource-extractive industries and those who would put an end to such industries in the state. In numerous localities throughout the state, rural areas are becoming urbanized. While resource conflicts and trade-offs are most obvious at the physical forest-urban interface; economic, political, and social forces with epicenters far from the forests are having the most profound effect on trends in use and forest ownership.

Physical losses of forest land during the past 10 years have been rather minimal, despite increasing urbanization, road and reservoir construction, and other activities. Timberland losses amounted to less than 300,000 acres, or about 0.2% per year. Loss of woodland amounted to another 200,000 acres or 0.1% per year. Road and reservoir construction usurped forest on both public and private lands, but urbanization—the single greatest factor—was confined to private lands.

Forest ownership is an important criterion in assessing trends in resource use. On the surface it would appear that forest ownership in California has been fairly static. The current distribution, shown in the following tabulation, is similar to that for 1975:

Ownership	Million Acres	Percent
National Forest	17.1	44
Other public	5.1	13
Private	<u>16.7</u>	<u>43</u>
Total	38.9	100

Within different ownerships, some notable changes have occurred that influence trends in use. Recent wilderness additions in national forests have increased the total area of reserved forest by about 1.1 million acres, and the area of reserved productive timberland by 450,000 acres. In the other public category, additions to national, state, and local parks amount to less than 100,000 acres. Management of national forests and other public lands has come under critical scrutiny by many interest groups, favoring either increased or decreased use of public resources in the marketplace.

National forests have supplied about 1.5 to 1.8 billion board feet of timber annually for many years (not counting the dip in timber harvest during the 1981-82 "timber recession"). This is about 38 to 40% of the state's total.

Private forest owners provided more than 70% of the wood used by forest industries before 1965, and about

60% since then. In 1986, 2.3 billion board feet were cut on private lands. An estimate based on a canvass of forest products mills indicates that 1.9 billion board feet came from forest industry lands, and 400 million came from farmer and miscellaneous private lands.

Private timberlands in California have been classified into three categories: 1) forest industry with mill(s) (timber companies that own land and manufacture forest products); 2) forest industry without mill(s) (large corporate ownerships on which the primary use of the land is growing and harvesting timber, although the owners do not operate mills); and 3) farmer and miscellaneous private (individual or corporate owners whose primary use of the land is for purposes other than growing timber). The following tabulation shows the distribution of these ownerships in California and the percent in timberland production zones (TPZ)<sup>3</sup>.

Ownership Class	Million acres	Percent TPZ
Forest industry with mill(s)	2.8	95 +
Forest industry without mill(s)	1.4	95 +
Farmer and miscellaneous private	<u>3.3</u>	39
Total	7.5	

In the past ten years several hundred thousand acres of timberland owned by companies that operated mills have changed ownership. Some of the new owners do not operate mills, although the land is still being managed for timber production. In some cases the land stayed in the same ownership, but the mills were sold. Most industrial land transactions have been followed by notable changes in management, and these potential changes in practices on a significant proportion of California's timberland are viewed with concern by state resource planners and policy makers.

Almost all of the physical loss of private forest land in California during the past ten years has been in the farmer and miscellaneous private category and primarily to urban development. Of the 3.3 million acres in farmer and miscellaneous private ownership, 1.3 million acres are in timberland production zones, and are less likely to be developed within the near future. The remaining 2.0 million acres are vulnerable to development.

Timberland production zones do not guarantee that forest land will remain in resource use: zones are in effect for only 10 years, and owners may appeal for zoning changes. A study by Romm and others (1983) examined many factors in relation to forest owner attitudes toward forest management, such as place of residence, age, level of education, personal financial status, and size of property. This study showed that land owners were more likely to favor timber management if wood products accounted for a high percentage of total employment in the county in which the property was

<sup>3</sup>Timberland production zones were recognized by the California Forest Taxation Reform Act of 1976 as lands on which growing timber is the highest and best use. Taxes are assessed on a reduced basis and in such a manner as to remove the incentive to cut stands prematurely.

located. It seems safe to say, however, that a large percentage of the farmer and miscellaneous private forest land will not be managed for timber, and is likely to be converted to nonforest use.

The appearance and condition of California's forests have changed markedly in the past ten years as a result of wildfires, insect and disease infestations, extremes of weather (both drought and flood), natural stand growth and development, timber harvesting, and other human activities. In 1987, an unusually bad year for fires, nearly 1 million acres burned, of which more than 250,000 were timbered. The fires killed an estimated 2.3 billion board feet of timber and 90,000 acres of young plantations. Although less spectacular than fire, insects and diseases killed 4 times the volume of timber and affected several times the area burned during the period 1975-1985.

The greatest change in forest condition in the past 10 years, however, is attributable to logging, which removed about 37 billion board feet of timber from several million acres and is changing the character of the forest—from rather open stands of large, old trees, to dense stands of small, young trees. In the north coastal redwood-Douglas-fir belt, for example, the size of the average sawtimber tree decreased over the past 10 years from about 25 inches to 20 inches (average tree volume decreased from 620 board feet to 410). At the same time, the total number of trees increased by 55%. The mix of species has also changed. In coastal areas hardwoods burgeoned as the conifers were harvested; in the interior, tolerant species such as white fir and incense-cedar increased as pines were removed from mixed-conifer stands.

Forest industrial consumption in California is dominated by lumber manufacturing to a much greater extent than in Oregon or Washington. Between 1976 and 1985 the proportion of the total harvest that went into producing lumber increased from 86% to 92%. Veneer and plywood production declined sharply, from 11% to 5%.

## Oregon

With 28.1 million acres of forest land, Oregon ranks third in the U.S. in forest area and fourth in area of timberland (2.1 million acres of timberland are reserved in parks and wilderness). It ranks first in total volume of available timber with 68 billion cubic feet. For several decades, it has also ranked first in volume of timber harvested.

Ownership distribution of forest land in Oregon is as follows:

Ownership	Million Acres	Percent
National Forest	12.6	45
Other Public	5.1	18
Forest Industry With Mills	5.4	19
Forest Industry Without Mills	0.5	2
Farmer and Miscellaneous Private	<u>4.5</u>	16
Total	28.1	100

Public ownerships account for 63% of the forest in Oregon. Included in the national forest total are 10.2 million acres of available timberland, 1.6 million acres of timberland in wilderness and other reserves, and 0.9 million acres of woodland. On national forest timberland, sites capable of producing 120 or more cubic feet of wood per acre amount to only 9% of the total, compared with 53% of forest industry lands and 45% of other private. In 1985 about 3.5 billion board feet of timber were cut on Oregon national forests. This is 43% of the total volume harvested in the state (from 47% of the available timberland). Unique to Oregon is the relatively large area of forest managed by the Bureau of Land Management (BLM)—2.7 million acres, of which 2.0 million acres is highly productive timberland. In 1985 BLM lands supplied about 900,000 million board feet of timber, 11% of the state's total, from 9% of the state's available timberland.

Other categories of public lands include state, county, municipal, and miscellaneous federal owners (National Parks, Department of Defense, and others). Indian lands managed under the guidance of the Bureau of Indian Affairs are also included in the public ownership category, though strictly speaking, they are private lands. The other public ownerships combined supplied about 425 million board feet in 1985, about 5% of the state's total.

In 1985, 3.0 billion board feet were harvested from forest industry lands. This is 37% of the total volume of timber harvested in Oregon, yet these industry lands account for only 19% of the timberland area. Companies that do not operate mills own extensive areas of forest dedicated to timber growing—primarily in the western part of the state.

Farmer and miscellaneous private forest lands include both small and large tracts owned by individuals as well as corporations. Although 45% of the timberland in this ownership is capable of yielding 120 or more cubic feet per acre, much of it is not being managed for timber production. Accounting for 16% of the timberland, this ownership contributed only 4% of Oregon's timber harvested in 1985.

A number of changes in Oregon's forest land base have occurred during the past 10 years. Within national forests, a nominal amount of new road construction, sizable additions to wilderness, and other decisions have reduced the total area of available timberland by about 1.3 million acres, or 11%. On BLM land, 448,000 acres of timberland were reserved from timber production; about 15,000 acres of forest were replaced by new roads.

Some erosion of the privately owned forest land base has occurred during the past 10 years. Within the timberland zone, losses amounted to less than 1%, mostly resulting from road-building. In the mixed-forest-agriculture zone losses amounted to about 3%; pasture clearing was the major cause. In the mixed-forest-urban zone, losses amounted to about 4%; as would be expected, urban-development and road-building were the major causes.

Most of the reduction in private forest area has been on farmer and miscellaneous private lands. However,

some noteworthy changes in ownership concerning forest industry lands are occurring. A substantial acreage of timber company property has been acquired by aggressive investment groups and international financiers. Another development is the acquisition of timbered properties by corporations based in Japan, People's Republic of China and Taiwan to secure timber for export. In most cases the land is not held by the foreign corporation after the timber has been harvested, but is reforested according to state law, then sold intact as timberland. These events may have important long-term effects on resources, local economies, and the environment.

The most obvious change in Oregon's forests over the past 10 years has been the reduction in area of old growth forests by logging, and the corresponding increase in area occupied by seedlings and saplings, especially on public lands (fig. 20). Much of the old growth on private lands was liquidated more than 10 years ago. On industrial private lands there has been a definite improvement in condition of the forest in terms of its ability to produce future crops of softwoods: in 1976 about 79% was occupied by manageable conifer stands; by 1986 this increased to 84%. Farmer and miscellaneous private lands have generally remained static, with about 64% that are well stocked with conifers in 1976 and 1986. Areas lacking manageable conifer stands are occupied by hardwoods, and inhibiting vegetation. Hardwoods have increased in area and volume for several decades on all ownerships, and have generally been regarded as weeds because they compete with conifers and have had little value on the market. The value of hardwoods, especially red alder, has been increasing recently, and timberland managers are beginning to look at hardwoods as a resource to manage.

The major uses of Oregon timber have been for lumber, veneer and plywood. Between 1976 and 1985 the relative amount of lumber produced from Oregon timber increased slightly from 58% of total wood consumption to 60%.

Plywood and veneer production declined from 35% to 30%. Production of pulp, posts, poles, pilings, and shakes and shingles decreased slightly while log exports increased—from 5% to 8% of total wood consumption.

Numerous forest-related issues have emerged, some involving the possible restriction of tree cutting in riparian strips. Other controversies represent regional or national issues and involve rare and endangered plants or animals, such as the provision of adequate spotted owl habitat, and protection of the Columbia River Gorge.

## Washington

Forest land totals 21.9 million acres in Washington, placing the state sixth in forest area in the Nation. Forests cover 46% of the land, making Washington the most heavily forested state west of the Mississippi. Ninety percent of the state's forests is productive timberland, most of which supports stands of Douglas-fir, western hemlock, ponderosa pine, and other conifers. With 64 billion



Figure 20.—By far the greatest change in Pacific Coast forests has been the reduction in area of old growth.

cubic feet, the state ranks a close second to Oregon in total volume of available timber. It ranks second to Oregon also, in total volume of timber harvested annually.

Ownership of Washington's forest is distributed as follows:

Ownership	Million Acres	Percent
National Forest	7.6	35
Other Public	5.6	25
Forest Industry	4.8	22
Farmer & Miscellaneous Private	3.9	18
Total	21.9	100

About 4.9 million acres of the 7.6 million acres of forest in national forests is available timberland, a reduction of about 0.3 million since 1975. Changes on both the plus and minus side include reserved area additions,



new road construction, expansion of ski areas, land acquisitions and deletions, and reclassification of some lands. Timber harvested from national forests in Washington has averaged about 1.2 billion board feet per year in recent years, about 20% of the total for the state.

Of the 5.6 million acres of forest in other public ownership, about 3.8 million are available timberland. The balance is split between productive timberland, primarily in national parks, and unproductive forest. Of the 3.8 million acres of available timberland, the State of Washington is the largest owner, with over 2 million acres. In 1985 about 1 billion board feet of timber was harvested on state lands, 17% of Washington's total, from 12% of the timberland. This was a sizable increase over the average of about 600 million harvested during the previous 4 years. About 1.4 million acres of timberland listed as other public are Indian lands. These are private lands owned by individuals or tribes, and are managed under the guidance of the Bureau of Indian Affairs. Indian lands have been contributing 200 to 300 million board feet, or roughly 4% of the total annual timber harvest in the state. Other public forests as a group are generally in good condition for continued timber production—88% are occupied by manageable conifer stands.

Forest industry lands in Washington have been undergoing some of the same kind of changes that have occurred in Oregon and California, with shifts between those companies with mills and those without, buyouts, and takeovers.

A large acreage, however, is held by companies that have remained fairly stable through the recent period of rapid change. Between 1965 and 1980, forest industry ownership increased by roughly 400,000 acres as forest industries acquired timberland, mostly from farmer and miscellaneous private owners. In recent years over 3 billion board feet have been cut annually on forest industry lands, about 55% of the total timber cut in the state from 22% of the forest land. Condition of the forest remains good on industry lands, with 88% occupied by manageable conifer stands.

Forest area in farmer and miscellaneous private ownership has been declining, mainly to urban expansion near major cities. From 1965 to 1980, about 270,000 acres of forest were lost. On the average these forests are in poorer condition than those in other ownerships: 78% are stocked with manageable stands, and 22% are occupied by cull trees, hardwoods, and brush. Farmer and miscellaneous private forest lands have been supplying about 10% of the wood consumed by forest industries in the state. About 900,000 acres of forest land in this ownership group is intermingled with areas developed for urban, industrial and agricultural uses. Much of these latter forests will probably be converted to non-forest in the future, and the remainder will probably not be used for continuous timber production.

In the past 10 years lumber production in Washington has remained fairly constant, but veneer and plywood, pulp, and post, pole and piling, and shake and shingle production have decreased. A major shift is the change in log exports, which between 1974 and 1984

increased 44%, from 1.6 billion board feet to 2.3 billion. Market and economic factors are responsible for most of the shifts, but declining availability of old growth western red cedar is thought to be the reason for the reduced production of shingles and shingles.

Other major changes in Washington during the past 10 years include a continued reduction in area and volume of old-growth timber (most notable in national forests because much of the old growth had already been logged on other lands); widespread tree mortality in eastern Washington caused by the combined effects of dwarf mistletoe, bark beetles, and budworms; and the eruption of Mount St. Helens, which directly affected about 125,000 acres of available timberland and killed 580 million cubic feet of live timber.

## Hawaii

Forests in the Hawaiian Islands cover 1.7 million acres, including 800,000 acres of productive timberland and 900,000 acres of woodland. There is little federal ownership of forest land in Hawaii, and no national forests. Hawaii's forest reserve system contains over 840,000 acres, most of which is owned by the state. Privately owned land within restrictive Conservation Districts totals 327,000 acres. There is little commercial wood harvesting on these lands.

Some wood harvesting is done of native koa, an attractive wood resembling black walnut and used for flooring, paneling, furniture and specialty items. Fast-growing exotic hardwoods are harvested for wood energy products on the island of Hawaii. Most of Hawaii's 46,000 acres of exotic plantations are eucalyptus.

The primary and essential resource produced in Hawaiian forests is water. Most of Hawaii's water supply comes from underground aquifers which are recharged by subsurface flow from forested watersheds. Some watersheds near cities are totally restricted from other use.

The protection and preservation of the unique endemic flora and fauna of Hawaii is a high priority. There is interest in sustaining or expanding production of a broad range of forest products, including koa specialty items, biomass from planted eucalyptus, tree fern products, various items made from plant parts gathered in the forest, and many more. In some areas, livestock grazing is the main use of the land, and in these areas the forests have been cleared or thinned to promote forage growth. Recreational uses of Hawaii's forests include hunting, fishing, hiking and sight-seeing, and tourism centered around the Islands' unique natural and cultural histories.

## RANGELANDS

The total area of rangeland in the five Pacific Coast states is 241 million acres (table 1). Not included are extensive areas of chaparral, pinyon-juniper, oak woodland, and conifer timber stands that are grazed by

livestock. If counted, these types would bring the total rangeland area up to well over 300 million acres. Pacific Coast rangelands can be classified into three broad ecosystem groups, identified by their location: those in Alaska; those in the three lower mainland states of California, Oregon and Washington; and those in Hawaii.

## Alaska

Alaska has about 173 million acres of rangeland, most of which is arctic and alpine tundra. In the Arctic tundra and Bering tundra provinces, cottongrass-tussock is widespread. Associated vegetation includes sedges, lichens, mosses, and forbs, along with several species of dwarf shrubs, including willows, birch, Labrador-tea, blueberry, and cinquefoil. In the Brooks Range region, lower elevations may be vegetated with a productive mat of sedges and shrubs. Cottongrass, bluejoint, mosses, lichens, forbs, and several species of dwarf shrubs are common. At higher elevations plant cover is discontinuous. Barren rock is intermingled with low mats of mosses, lichens, forbs, dwarf birch, crowberry, Labrador-tea, willow, and blueberry. Alpine tundra also occurs in the Alaska Range, north to the Yukon River. Extensive bogs occupy old river terraces, ponds, and sloughs. Vegetation there is chiefly sphagnum and other mosses, aquatic forbs, sedges, bog rosemary, and Labrador-tea.

Alaskan rangelands are variable in productivity. Though the cottongrass-sedge-dwarf shrub and bluejoint types can produce up to 1,000 pounds of forage per acre, most rangeland areas produce well under 500 pounds. These rangelands support large populations of caribou, moose, and about 30,000 reindeer. They also support numerous other animals indirectly through the food chain, including bears, wolves, coyotes, foxes, squirrels, mice, and many others.

Ownership of rangelands in Alaska has changed dramatically in the past 10 years. Formerly, about 97% was in federal ownership, most managed by the BLM. The BLM now manages 59 million acres, about 34%.

The Forest Service administers 2.5 million acres. The remainder is held by private owners (mostly native Alaskans), the State of Alaska, and other federal agencies, such as the National Park Service.

Important to the livelihood of some native Alaskans are the reindeer, which supply meat, milk, hides and horns. The lichens of the arctic tundra are critical for the subsistence of the reindeer. It is estimated that about 40% of the lichen resource has been severely damaged by overgrazing and recurring wildfires. The Soil Conservation Service is working with other groups including native Alaskans, University of Alaska, and other government agencies to study growth and management of lichens, to develop and apply improved range management techniques to these lands (critical because of the long time required to revegetate overgrazed lichens), to provide technical assistance in making range site inventories, and to study the population dynamics of reindeer (Galt 1988).

## California, Oregon, and Washington

The rangeland ecosystems in these three states are similar to those of the Rocky Mountain Section. Total rangeland area is about 71 million acres, including 23 million acres of grassland and 48 million acres of shrublands. Not included are about 8 million acres of chaparral, 7 million acres of oak woodland, 5 million acres of pinyon-juniper woodland, and 4 million acres of other conifer woodland, most of which produce forage, and are grazed.

Grasslands are divided into mountain grasslands (40%), mountain meadows (6%), annual grasslands (41%), alpine grasslands (13%), and wet grasslands (trace). Mountain grasslands are found in all three states. Plant species present in this ecosystem vary considerably from place to place, but commonly include species of wheatgrass, fescue, brome, needlegrass, bluegrass, wild rye, balsamroot, wyethia, rabbitbrush, sagebrush, and bitterbrush. Mountain meadows are also found in all three states, but are more common in California. Bluegrass, pinegrass, fescue, sedges, false hellebore, lupine, buckwheat, and numerous small forbs are typically found in mountain meadows. Alpine grasslands, also found in all three states above timberline, may contain species of bluegrass, fescue, brome, needlegrass, sedges, phlox, lupine, buckwheat, gilia, penstemon, avens, aster, buttercup and numerous other small forbs. Annual grasslands, found in the foothills surrounding the Great Central Valley in California, are dominated by introduced annuals that have replaced the native perennial bunchgrass (most of which was needlegrass). Among the annuals that now occupy these extensive grasslands are wild oats, fescue, brome, barley, dogtail grass, medusahead, and numerous forbs including filaree, dock, poppy, mountain dandelion, lotus, clover, and tarweed. The annual grasslands merge with the oak woodlands at higher elevations in the foothills. Annual grassland plants are common in much of the blue oak, interior live oak and valley oak woodland types. For this reason the oak woodlands and "savannas" are often considered to be part of the California annual grasslands (Barbour and Major 1977).

Shrublands are divided into sagebrush (52%) and desert shrub (48%). The sagebrush ecosystem includes several major and numerous minor associations. Most extensive is the big sagebrush group in which one of the several varieties of *Artemesia tridentata* dominates. Other shrubs may include rabbitbrush, bitterbrush, mountain-mahogany, granite gilia, currant, serviceberry, and snowberry. Common grasses are fescue, wildrye, wheatgrass, bluegrass, squirrel-tail and needlegrass. Low sagebrush and stiff sagebrush types are found on poorer sites than big sagebrush. Low sage is common in northeastern California on low-lying, poorly drained sites within the big sagebrush type and as inclusions within ponderosa pine and western juniper types. Stiff sagebrush is common in eastern Oregon and eastern Washington on very shallow, stony soils. Pinyon-juniper type, for the most part, occurs within sagebrush communities, and is considered by some to be part of the sagebrush ecosystem.

Desert shrub ecosystems include about 3.5 million acres in southeastern Oregon and nearly 20 million acres in California, mostly in the southeastern portion. In Oregon, desert shrub types include saltbush, shadscale, and greasewood communities. They occur on saline soils in low-lying areas often intermingled with upland sagebrush communities. Other shrubs present include spiny hopsage, bud sagebrush, and winterfat. Grasses include giant wildrye, alkali saltgrass and Indian ricegrass (Franklin and Dyrness 1973).

In California, desert shrub ecosystems include saltbush, shadscale, creosote bush, blackbush, and Joshua tree woodland communities. Creosote bush is one of the most extensive types in the Mojave Desert. It is found from below sea level in Death Valley to elevations of 5,000 feet elsewhere. Among its many associates are shadscale, saltbush, encelia, Mormon tea, krameria, yucca, prickly pear, and ragweed. Blackbush type is widespread in the desert from about 4,000 feet in elevation up to 6,000 feet. It is found in cooler areas than creosote bush. Generally, blackbush grows where snow occurs for short periods during the winter. Associates include spiny hopsage, Mormon tea, winterfat, shadscale, bud sagebrush, horsebush, yucca, and buckwheat. Joshua tree woodland occurs along the fringes of the pinyon-juniper woodland, and within blackbush and shadscale types (but generally on lighter, less rocky soils). Some of the same associates found in blackbush and shadscale types are found as understory plants in Joshua tree woodland. Other associates include yucca, bladder-sage, haploppappus, galleta, and muhlenbergia. (Barbour and Major 1977).

The productivity of rangelands in California, Oregon, and Washington is extremely variable. Desert ecosystems produce up to 250 pounds of forage per acre on better sites, while grasslands may produce up to 5,000 pounds. Annual grasslands have the highest productivity of any of the extensive types, averaging more than 2,000 pound per acre. The better sites may produce over 3,000 pounds (Garrison et al. 1977).

In California, Oregon, and Washington combined, 51% of the rangeland is owned by the federal government. Ownership distribution varies by state (table 15).

About two-thirds of the federal rangeland is administered by the BLM. In California, nearly 3 million acres are in military reservations. Other federal owners of rangeland include the Forest Service, National Park Service, Corps of Engineers, Bureau of Reclamation, Fish

and Wildlife Service, and native Americans. Nonfederal owners include the states and other local governmental agencies, and private individuals and corporations.

The most productive rangelands, and those most manageable in terms of accessibility and physiography, are usually in private ownership. These are the mountain valleys and the highly productive annual grasslands of California. The California desert, the sagebrush types and the high mountain grasslands are in federal ownership.

Rangeland area has decreased during the past 10 years in the three states, but losses have been comparatively light. Little change has occurred in distribution by owner group, but a considerable area of privately owned rangeland has changed owners in the past decade in parts of California. In many areas, pinyon-juniper type has spread into treeless or near-treeless rangeland during the past century, and most noticeably since about 1930. Studies have documented the tremendous water demands of western juniper, and in some areas juniper clearings have resulted in dramatic increases in nearby streamflow. Western juniper and pinyon-juniper have been eradicated in numerous range improvement projects in eastern Oregon and California in the past 20 years. These projects appear to have neutralized the spread of pinyon-juniper type (Bedell 1985).

Range condition has changed dramatically throughout the Pacific Coast states since Europeans first appeared. Misuse and overuse resulted in degradation of rangeland until range conditions reached a low point in the 1930s. In most areas range condition has been improving since then, as government range managers, and ranchers with technical and financial assistance from the Government, have worked to correct the problems created decades to a century before.

The Soil Conservation Service (SCS) evaluates range condition by comparing the present vegetation of a site to the climax vegetation that a given site could support. The climax type is the most stable, therefore the least susceptible to erosion or other degradation (but not necessarily the most desirable for specific uses an owner may desire). For nonfederal rangelands in California, Oregon, and Washington, excluding recently-seeded rangeland and the annual grasslands of California (which are now dominated by introduced plants and cannot be rated by SCS's system), the SCS has rated range condition as follows:

Table 15.—Ownership and percent of rangeland area (million acres) for California, Oregon and Washington, 1987

State	Federal Ownership		Nonfederal Ownership		Total
	Million acres	Percent	Million acres	Percent	
California	18.8	49	19.7	51	38.5
Oregon	12.6	57	9.4	43	22.0
Washington	1.9	25	5.6	75	7.5
Total	33.3	—	34.7	—	68.0

Condition	Percent of rangeland
Excellent (75% + of present community is climax)	6
Good (51 - 75% climax)	21
Fair (26 - 50% climax)	36
Poor (25% and less climax)	37

An evaluation by SCS of the treatment needed on all rangeland in nonfederal ownerships showed that 26% of the rangelands were adequately protected; treatment was not feasible on 15% of the rangelands, because a reasonable economic return was not likely; and conservation treatment was needed on the remaining 59%. Six conservation treatment practices are recommended in California, Oregon, and Washington, on nonfederal lands. They are:

Conservation Treatment	Percent of Nonfederal Rangeland
Protection only	26
Improvement without brush management	19
Improvement with brush management	18
Re-establishment	8
Brush management and re-establishment	10
Erosion control	19

## Hawaii

Rangeland area is estimated to total 1.4 million acres in Hawaii. Most of the original native plants on Hawaii's rangelands have been replaced by introduced perennials.

The major conservation practices needed are planned grazing systems (intensive grazing management); proper range use; fencing (4,000 miles in 7 years); and providing pipelines, troughs, and tanks (livestock water). Intensive grazing management is being practiced on about 40,000 acres in the state.

## WATER AREA

Within the Pacific Coast states are 20.1 million acres of water. Of this, about 1.6 million acres are in coastal waterways such as Puget Sound, Strait of Juan de Fuca, and San Francisco Bay (Alaska's coastal waterways are excluded). Inland water makes up the remaining 18.6 million acres, about 87% of which is in large bodies of water (lakes at least 40 acres in size and streams at least 1/8-mile wide). Numerous natural and artificial bodies of water are included: Lake Tahoe; Crater Lake; Lake Roosevelt, created by Grand Coulee Dam; and a long list of rivers, including the Columbia and Yukon, and many lesser rivers such as the Sacramento, San Joaquin, Willamette, Umpqua, and Rogue. The remaining 13% of inland water is made up of lakes and ponds between 2 and 40 acres in size and streams between 120 feet wide and 1/8-mile wide. In this category are numerous tributary streams such as California's Feather and Mokelumne Rivers; Oregon's Deschutes, John Day, and McKenzie Rivers; and Washington's Okanogan, Nisqually, and Puyallup Rivers.

More than 80% of the total area of inland water in the Pacific Coast Section is in Alaska. Besides the numerous large rivers such as the Yukon system, more than 3 million lakes over 20 acres in size are scattered throughout the state.

## CHAPTER 6: OTHER RESOURCES OF THE LAND BASE

### MINERALS AS FOREST AND RANGELAND RESOURCES

Minerals are significant forest and rangeland resources, and most mining takes place on forest and rangelands. In part, this is because area in forests and rangelands is larger than in any other land use category. Further, the mountainous topography and high elevations (with harsh weather), where much of the mining occurs, have deterred other uses and made the lands most suitable for forest and range. Because minerals lie beneath the land's surface, development of mineral resources affects management of surface resources. Likewise, reservations of land for specific surface uses and values affect the availability of subsurface minerals.

There are some 2,500 minerals, broadly defined as any material from the earth that might be used in home or industry (Wenner 1984). About 100 of these substances are of worldwide economic importance.

For purposes of analysis, minerals can be placed in three broad categories:

- Energy minerals, including oil, coal, oil shale, tar sands, uranium, and geothermal resources.
- Metallic minerals such as iron, aluminum, chromium, cobalt, molybdenum, copper, lead, gold and silver.
- Non-metallic minerals and mineral materials, including common construction materials such as sand and gravel; fertilizer corundum; chemical minerals such as arsenic and salt; and gems like diamonds and emeralds used in jewelry and some industrial processes.

Unlike renewable resources that can be subject to rather precise inventory or, in the case of timber, calculation of growth rates with reasonable accuracy, there is considerable uncertainty about the extent of the Nation's minerals resources.

#### Energy Minerals

There is disagreement among experts over the extent of the Nation's reserves of petroleum, and supplies are uncertain over the long term. It appears that most of the easily-recoverable supplies of petroleum have been depleted; oil fields in the contiguous 48 states have been pumped for many years, and recovery rates are declining (Abelson 1987; Fisher 1987). The average output of domestic wells in 1984 was 14 barrels a day, compared to 12,011 in Saudi Arabia (Abelson 1987). According to the U.S. Department of Energy, the United States in 1985 had proven reserves of 28.4 billion barrels of crude oil (about a 9-year supply at current production rates), and an estimated 82.6 billion barrels of undiscovered recoverable crude oil (U.S. Department of Energy 1987).

However, other experts contend that there are 300 billion barrels of oil that could be recovered, although it would require expensive new technology (Abelson 1987; Fisher 1987). In fact, the U.S. continually adds to its reserves through technology that makes oil economically recoverable, enlargement of proven reserves, and new discoveries. The 9-year reserves-to-production ratio has held at that level or higher for more than three decades (U.S. Department of Energy 1987).

The United States also has substantial amounts of natural gas. A 1988 study for the Department of Energy estimated that technically recoverable natural gas in the U.S. reserve and resource base amounted to 1,188 trillion cubic feet (Argonne National Laboratory 1988). This figure includes 1,059 trillion cubic feet beneath the 48 contiguous states, and another 129 trillion cubic feet in Alaska. Of the 1,059 trillion cubic feet of natural gas deemed to be technically recoverable in the lower 48 states, more than half—583 trillion cubic feet—is judged to be economically recoverable at a wellhead cost of less than \$3 (1987 dollars), including finding costs, per million cubic feet. If this is the case, the U.S. has, at current levels of consumption, a 35 year supply of natural gas at a cost equal to or below \$3 per million cubic feet (Argonne National Laboratory 1988).

The United States has abundant supplies of coal, with reserves estimated to be 478.2 billion short tons (U.S. Department of Energy 1985). The U.S. now consumes less than a billion tons of coal per year. Coal can substitute for oil for power generation and some heating uses. Some authorities foresee significantly increased use of coal as domestic oil becomes more expensive to develop (Lansberg 1987). However, there are serious environmental concerns—notably acid deposition—associated with its use which need to be overcome if coal is to realize its potential. The United States also has large reserves of oil shale, with estimates ranging from the equivalent of several hundred billion barrels of oil to more than a trillion barrels (Abelson 1987).

The nation also has large amounts of uranium, if required for power generation, and the potential for increased use of geothermal resources (U.S. Department of Energy 1985).

#### Metallic Minerals and Precious Metals

Overall, the Nation has large quantities of many metallic minerals. In 1986 it was among the world's top producers of 33 of the 87 minerals monitored by the U.S. Department of Interior's Bureau of Mines, and a major producer of a number of others (U.S. Department of Interior, Bureau of Mines 1985). For example, the domestic reserve base (identified resources which may reasonably

become economic to exploit) of copper amounts to 90 million tons, enough to last 47 years at 1985 consumption rates. The domestic reserve base of lead amounts to a 23-year supply. The reserve base of gold would last 39 years; silver, 14 years; and molybdenum, 353 years (Department of Interior, Bureau of Mines 1987b).

However, relatively little is known about the actual extent of the Nation's minerals reserves. Moreover, their use is influenced by accessibility; cost of exploration, development, and production; and by the availability of technology that permits their extraction in an environmentally-sound manner at competitive cost. Most of the minerals available in the United States are available in other countries as well. The world price of a mineral affects the competitive position of domestic producers. For example, while the United States has substantial reserves of copper, in 1987 it imported about half of the copper consumed domestically because it was cheaper to buy it overseas than to exploit domestic sources (U.S. Department of Interior, Bureau of Mines 1987a).

Some minerals are in short supply domestically or deposits are of such low quality that they cannot be produced economically; thus the United States relies almost exclusively on foreign sources. Some minerals are of great economic and strategic importance (Hargreaves and Fromson 1983). For example, the U.S. imports 100% of the manganese and columbium (both used to increase the hardness and durability of steel) it consumes, 94% of the cobalt, 92% of platinum-group metals, and 92% of industrial diamonds (U.S. Department of Interior, Bureau of Mines 1987a). For some of these minerals, potential economic and political instability of the source countries raises questions of supply security (Hargreaves and Fromson 1983).

The Nation's reserves of metallic minerals, like energy minerals, are not static; changes in world prices or more efficient mining and processing technologies could make current uneconomic reserves profitable to develop or stimulate a search for new reserves. Also, ores predominantly of one mineral often contain another mineral that can be economically produced as a byproduct or co-product. For example, cadmium is produced as a byproduct of zinc (Hargreaves and Fromson 1983).

### Non-Metallic Minerals and Minerals Materials

Nationwide, supplies of minerals materials used in construction, such as sand, gravel, stone, and clay, are virtually inexhaustible (U.S. Department of Interior, Bureau of Mines 1985). However, because of their weight and bulk, transportation is costly and as a practical matter, they are usually produced near where they are to be used. There are areas where some important construction materials, such as sand and gravel, occur in limited amounts or are nonexistent and local shortages do occur. In areas where supplies of mineral materials exist, land use and environmental constraints are major factors limiting development (U.S. Department of Interior, Bureau of Mines 1985). The nation possesses significant reserves of fertilizer minerals; however, there are concerns over the environmental impacts of phosphate mining in Florida, where most U.S. phosphate is produced.

### Location of Minerals

The areas of highest mineralization are the mountains and basins of the West and the Appalachian chain in the East. However, minerals of economic importance are widely scattered throughout the United States. For example, there are identified iron deposits in all but six states.

Coal underlies about 13% of the Nation and occurs in 37 states (U.S. Department of Agriculture, Forest Service, 1979). The bulk of the Nation's coal reserves, however, are located beneath the Allegheny Plateau and the Cumberland Plateau in the East, the Ohio and Mississippi River Valleys and the Great Plains (U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement 1987). Oil deposits are concentrated in an area extending from Oklahoma south to central Texas, with scattered deposits beneath the eastern plateaus and western basins (U.S. Department of Energy 1985). Geothermal resources occur mainly in the West, although there are areas of geothermal activity in the Appalachians and along the Atlantic Coast. (Honig et al. 1981).

Although deposits of individual metallic minerals may be found in many areas of the Nation, production is typically far more limited. For example, although there are deposits of copper throughout the Appalachian Mountains, Missouri, Oklahoma, Michigan, Minnesota and all the western contiguous states, only six states (Arizona, Michigan, Montana, Nevada, New Mexico, and Utah) produce significant amounts of copper, and the bulk of U.S. production comes from Arizona and Utah. Beryllium is produced at a single mine in Utah, although there are deposits in Alaska and Texas as well (Bureau of Mines 1987a).

### Ownership of Minerals

There is little information on the quantities of minerals in public and private ownership. In part this is because relatively little is known about what mineral deposits actually exist. Further, no agency maintains statistics on the ownership of known deposits. The ownership of metallic minerals is extremely complex and often transitory. For example, those minerals deemed locatable under the Mining Law of 1872 (generally, metallic minerals and uranium on public lands in the 11 contiguous western states and Alaska) on federal lands become private property with their discovery and the filing of necessary legal papers (Leshy 1987). The key question is not one of who owns the minerals, but whether they are accessible and available for development, and under what conditions.

Somewhat more is known about the federal government's ownership of energy minerals, since these minerals are subject to lease. In the West, the federal government owns about 60% of the 234 billion tons of identified coal reserves (U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement 1987). In the East, where there is relatively little public land, the majority of coal is privately owned. About 6.5 million acres of the 191 million-acre National Forest System is known to be underlain by coal. Another 45 million acres is believed to have oil and gas potential, and 300,000 acres have potential for oil shale (U.S. Department of Agriculture Forest Service 1985).

## Mining on Forest and Rangelands

There is relatively little information specific to mining on forest and rangelands, public or private. There are some national data, although now nearly 10 years old, on land used for mining. Since most mining takes place on forest and rangelands, it provides generalized information on the extent of mineral development on these lands. In addition, federal agencies maintain information on various aspects of mineral development, such as mining permits issued, acreage under permit, and sales and leases on federal lands. Collectively, they provide a picture, though fragmentary, of the extent of mining on the Nation's forest and rangelands.

Mining occurs on only a small fraction of the Nation's land. Between 1930 and 1980, about 5.7 million acres had been used for mining for all types of minerals<sup>4</sup> (Johnson and Paone 1982.) This amounts to about one-quarter of one percent of the Nation's land, an area about equal to the State of New Hampshire. By contrast, some 27 million acres are devoted to highways, rural roads, railroad rights-of-way, and airports (Frey and Hexem 1985). With regard to the long-term pre-emption of other uses, the effect of some kinds of mining is not as severe as the conversion of forest and rangeland to urban development, where there is little probability that the land ever will be returned to forest or range.

Even though it involves a small area compared to the Nation's total area, mining activity can have a disproportionate impact on some areas. For example, six states—Pennsylvania, Kentucky, West Virginia, Ohio, Illinois, and Indiana—accounted for nearly half of all the land used for mining between 1930 and 1980 (Johnson and Paone 1982). During the period more than 1% of the land area of each state was mined, and three states (Pennsylvania, Kentucky, and West Virginia) had more than 2% of their land used for minerals extraction (table 16). In each of these six states plus California and Florida, mining used more than 250,000 acres. Within states, some areas are intensely affected. Of the 121,820 acres used for mining in Arizona, 91,200 acres were in the state's copper region. Similarly, 90,000 acres have been mined in northern Minnesota's Mesabi Iron Range (Johnson and Paone 1982).

According to the Department of Interior, Bureau of Land Management (1987), about 732 million acres of federal land are subject to surface and subsurface mineral-development, the majority of it in the West and Alaska. As of September 30, 1986, nearly 95 million acres were under lease for oil and gas, just over 2 million acres had been leased for geothermal development, and another 1.3 million acres had been leased for coal. While the minerals under this land are subject to extraction, it does not mean that all the surface will be disturbed as a result of development. Data on leases for some important minerals on federal land are shown in table 17.

<sup>4</sup>Area includes area of surface mine excavation, area used for disposal of surface mined waste, surface area subsided or disturbed as a result of underground workings, surface area used for disposal of underground workings, and surface area used for disposal of mill or processing wastes. It does not include land used for haulroads, fresh water reservoirs, railroads and public highways to edge of mining properties, or streams affected by acid drainage and sedimentation (Johnson and Paone 1982)

Table 16.—States leading in amount of land used for mining 1930-1985, by total land area, acres mined, and percent of total area

State	Total land area	Acres mined	Percent
			of total
	Thousand acres	Acres	
Pennsylvania	28,805	635,530	2.21
Kentucky	25,512	533,410	2.09
West Virginia	15,411	318,120	2.06
Ohio	26,222	507,320	1.93
Indiana	23,158	260,660	1.13
Illinois	35,795	411,380	1.11

Source: Johnson and Paone 1982.

While there are no figures on acreage being mined on the national forests, data on national forest minerals production confirm that significant amounts of some important minerals are extracted from the national forests (table 18). In 1986, the national forests were major contributors to the Nation's production of molybdenum (69% of national production), lead (63%), gold (15.1%), silver (13%), copper (6%), and phosphate (5%). In terms of energy minerals, the national forests in 1986 produced 11.4% of the Nation's output of uranium and 4.6% of its coal, but only 1.2% of the natural gas and .00059% of the oil produced domestically.

## Reclamation of Mined Lands

Once the mineral deposit has been removed, the land can be reclaimed and returned to other uses. A 1982 study of land used for mining of all types between 1930 and 1980 estimated that some 2.7 million acres, or 47% of the 5.7 million acres of land disturbed had been reclaimed by industry (Johnson and Paone 1982). The Surface Mining Control and Reclamation Act (SMCRA) requires reclamation of land disturbed for coal mining; thus it is presumed that all land mined since 1977 has been or will be adequately reclaimed. Since 1977, more than 10,000 abandoned mine sites (primarily coal), and nearly 65,000 acres have been treated through the Abandoned Mined Land Program established by SMCRA (St. Aubin and Massie 1987).

It is difficult, however, to determine the pace of reclamation of abandoned coal mines, the extent of reclamation of non-coal mines, or the adequacy of reclamation efforts under SMCRA. Johnson and Paone (1982) cite a 1979 Bureau of Mines report indicating that about one million acres of coal lands mined between 1930 and 1971 "remained in an abandoned state." If that estimate was reasonably accurate, less than 10% of abandoned lands have been treated under the Abandoned Mined Land Program. Some private groups have been critical of the implementation of SMCRA, claiming that enforcement of the law's provisions by the Office of Surface Mining Reclamation and Enforcement have been lax and haphazard (Dunlap and Lyon 1986). The General Accounting Office (GAO) also noted difficulties in reclaiming surface mined land on which operators had forfeited

Table 17.—Minerals leases, licenses, permits and application on federal land for selected energy and non-energy minerals

Mineral	Leases in effect as of Sept. 30, 1986		Leases issued in FY 1986	
	Number	Thousand acres	Number	Thousand acres
Oil and gas	102,885	92,729.9	9,009	9,927.4
Geothermal	1,212	2,039.1	144	242.6
Coal Leases	1,190	1,353.9	13	20.7
Licenses permits & applications	278	438.6	5	1.5
Uranium <sup>1</sup>	131	34.1	1	.8
Phosphate <sup>1</sup>	307	207.3	—	—
Lead	193	110.5	10	6.7

<sup>1</sup>Includes all leases, lease applications, and prospecting permits.

Source: Derived from tables 36-40 in U.S. Department of Interior, Bureau of Land Management, 1987.

Table 18.—Estimated production of selected minerals on national forest land for 1986 compared to total national production

Mineral	Units	Production on National Forest Land	Total domestic production	Percent of production on National Forest Land
Crude oil	M barrels	18,917	3,168,252,000	( <sup>1</sup> )
Natural gas	MM cu f	189,663	15,991,000	1.19
Coal	M sh tons	41,221	890,315	4.63
Uranium	MM lbs	1.50	13.20	11.36
Geothermal	Kilowatts	17,677	1,580,000	1.1
Lead	metric tons	223,455	353,115	63.28
Phosphate	M metric tons	1,814.91	38,700	4.69
Copper	metric tons	93,995.102	1,479,432	6.35
Molybdenum	M lbs.	65,275	3,976	69.46
Gold	M troy oz	563.80	3,733	15.10
Silver	MM troy oz	4,455.84	34,200	13.03
Limestone	M sh tons	1,833,92	767,250,000	( <sup>1</sup> )
Sand & gravel	MM sh tons	13,223,50	88	31.5

<sup>1</sup>Less than 0.5 percent.

Source: U.S. Department of Agriculture, Forest Service, Minerals and Geology Management Staff 1988; and U.S. Department of the Interior, Bureau of Mines 1986.

performance bonds in Pennsylvania and West Virginia (General Accounting Office 1986).

### Effects of Mining on Surface Resources

Mining can have a significant effect on surface resources. However, the effects are highly variable depending on the mining method, the mineral, the processing technology used, and the ecological nature of the site. Potential impacts include preemption of land for other uses, destruction or impairment of fragile ecosystems and wildlife habitats, contamination of surface and subsurface water supplies and soils from toxic chemicals and radioactivity, and adverse effects on scenic values (National Research Council 1979, Council on Environmental Quality 1981). Although effects are most apparent while the mine is active, some effects—such

as pollution of water from waste seepage, or large areas of waste tailings—can persist long after mining has been discontinued. While most of the adverse ecological affects can be prevented or mitigated through care and thorough reclamation, a 1987 report by the Environmental Protection Agency placed mining in the second of six ranked categories of ecological risk, behind ozone depletion and atmospheric CO<sub>2</sub> and global warming, and equal in risk to the physical alteration of aquatic habitats (U.S. Environmental Protection Agency 1987).

Mining preempts most surface uses, but the reverse is also true. Surface use or the designation of special management regimes to protect surface uses or values can effectively preclude or prohibit mineral development. The development of an urban shopping mall effectively prevents the development of whatever mineral resources may lie beneath it. The development of a forest campground or visitor center makes development of

mineral resources doubtful. Statutes have explicitly limited mining on forest and rangelands. Under provisions of the National Wilderness Preservation Act, no mineral exploration has been permitted in national forest wilderness areas since 1984. The Surface Mining Control and Reclamation Act prohibits surface mining for coal on the national forests. The forest land management plans being prepared by individual national forests are likely to further constrain exploration and development of leasable minerals. It is not known how much of the Nation's forest and rangelands is precluded from mining because of statute, administrative fiat, or private land-owner objectives, but it is substantial.

## THE NATION'S WETLANDS

Wetlands include marshes, swamps, bogs, small ponds, sloughs, potholes, river overflows, oxbows, mud flats, and wet meadows. They are generally lands where saturation with water is a dominant factor that determines the nature of soil development and the types of plant and animal communities that live in the soil and on the surface. They are transition lands between terrestrial and aquatic systems where the water table is usually at or near the soil surface or the land is covered at least part of the year by shallow water. These lands deserve special attention because this portion of the Nation's forest and rangeland base has high biological productivity and is important as habitat for wildlife and fish at critical times in their life cycle.

Estimates of the original wetland acreage present in the United States at the time of settlement vary, however, a reliable account places the extent at 215 million acres for the conterminous United States (Roe and Ayres 1954). In 1906, the U.S. Department of Agriculture conducted one of the first wetlands inventories and estimated the total at 127 million acres (Shaw and Fredine 1971). Estimates for the mid-1970s place the total at about 99 million acres (Frayer et al. 1983). These inventories have shown conclusively that wetland acreages are declining. Thus, today's wetland resource in the United States probably represents less than 46% of our original wetlands and 78% of those present at the turn of the century.

The U.S. Fish and Wildlife Service classifies wetlands and deepwater habitats into five ecological systems (Cowardin et al. 1979). The most important from the perspective of forest and rangeland, the Palustrine System, encompasses the vast majority of inland marshes, bogs, and swamps. The palustrine forested wetlands occur mostly in the eastern United States and Alaska. In the East, they are the most abundant wetland type. They include black spruce bogs, cedar swamps, red maple swamps, and the bottomland hardwood forests that dominate our major river systems. In the mid-1970s, of the 94 million acres of palustrine wetlands present in the conterminous United States, nearly 50 million acres were forested.

The Nation's wetlands are mostly privately owned. The U.S. Fish and Wildlife Service estimates that there were approximately 95 million acres of wetlands in the United States in 1985 (U.S. Department of Interior, Fish and Wildlife Service 1988). Of this total, about 70 million acres of

the wetlands were in private ownership, 12 million acres were administered by federal agencies, and the remainder was owned or administered by other public agencies.

An indication of the trend in wetland gains and losses is documented in the U.S. Fish and Wildlife Service report that deals with the 20-year period between the mid-1950s and the mid-1970s (Tiner 1984). During this period, wetland flats increased 200,000 acres, and about 2.1 million acres of ponds and reservoirs were created. Pond acreage nearly doubled from 2.3 million acres to 4.4 million acres, primarily due to farm pond construction in the central part of the United States. Most of the pond acreage came from former upland pastures, although 145,500 acres was forested. Despite the gains in wetlands from new ponds and reservoirs, beaver activity, and irrigation and marsh creation projects, the losses of wetlands during the period were enormous. Eleven million acres were destroyed, but the net loss was reduced to 9 million acres because of the 2 million acres of newly created wetlands. Agricultural development involving drainage was responsible for 87% of the national wetland losses and urban and other development was responsible for the remaining 13%.

Agriculture had the greatest impact on forested wetlands, accounting for a loss of 5.8 million acres. Greatest losses took place in the Lower Mississippi Valley with the conversion of bottomland hardwood forests to cropland. Shrub wetlands were hardest hit in North Carolina where many pocosin wetlands were converted to cropland and pine plantations or were mined for peat. Inland marsh drainage for range and agriculture was most significant in the prairies of the Dakotas and Minnesota, the sandhills of Nebraska, and in the Florida everglades.

## SOIL PRODUCTIVITY AND MANAGEMENT

Land uses and resource outputs are influenced to a considerable degree by soils. The quality and quantity of range, recreation, timber, water, wilderness, and wildlife resources are directly related to the inherent productivity and the existing condition of the soil resource. Often this relationship is incompletely understood, but typically, high inherent soil productivity and favorable existing soil conditions result in more flexible management opportunities and increased resource outputs.

Soil characteristics and soil management concerns may vary greatly over short distances, yet broad regional trends can be recognized. Figure 21 displays three major soil management concerns: land mass failure hazard (landslides), severe surface erosion hazard, and high water tables. The circles within each section represent total National Forest System (NFS) acres, with the relative portions representing lands identified with one of the three major soil management concerns. The discussion that follows concerns NFS lands; but parallels can be drawn for forest and rangeland of other owners in the same section of the country.

The total NFS land area affected by major soil management concerns ranges from about 25% in the Rocky Mountains and Great Plains Sections to slightly less than 50% in the South Section. Severe surface erosion hazard

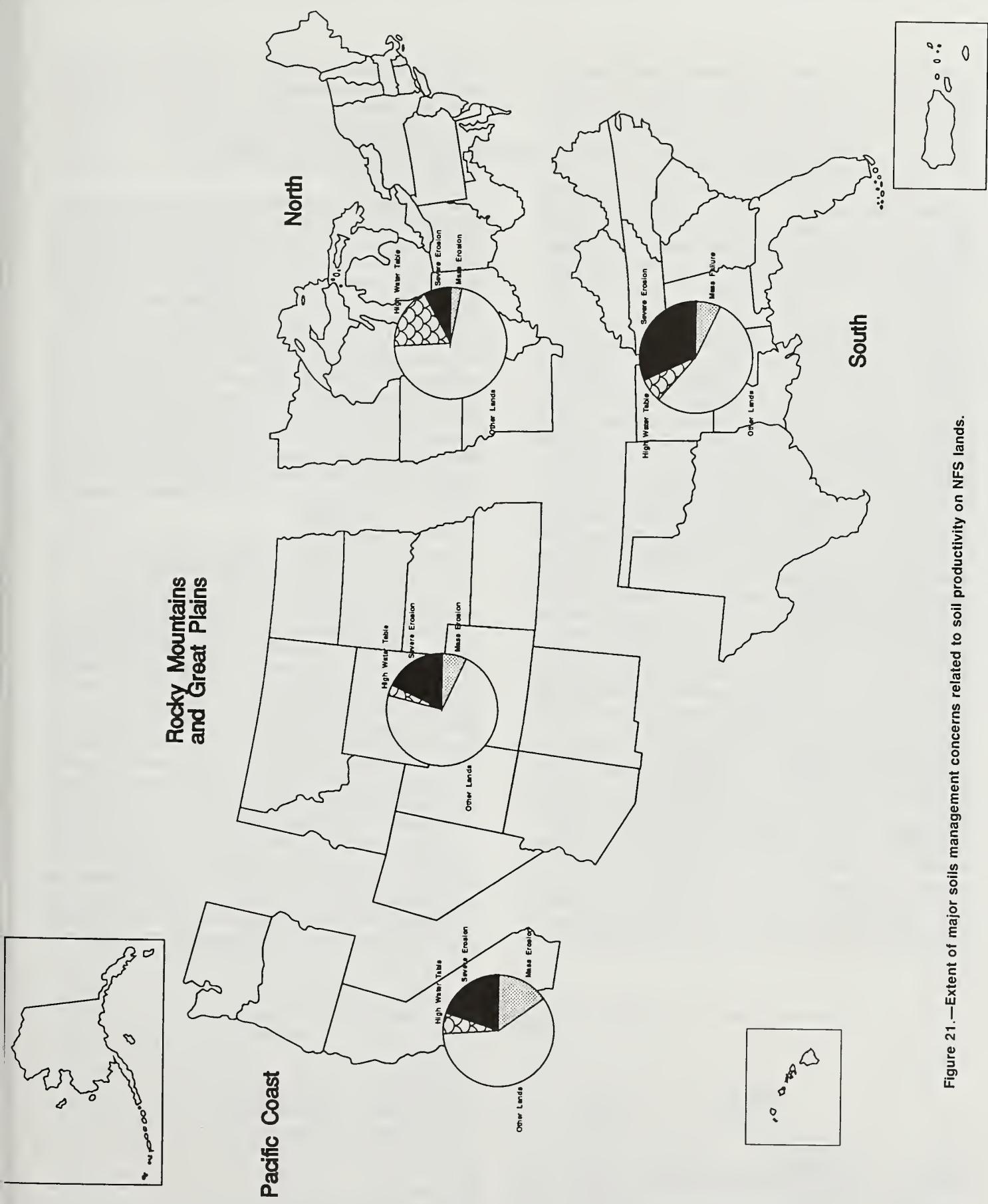


Figure 21.—Extent of major soils management concerns related to soil productivity on NFS lands.

is identified as the leading major soil management concern in all but the North Section. A total of 33,784,000 acres of NFS land nationally have severe surface erosion hazards. Land mass failure hazards are a significant concern in the South and Pacific Coast Sections, primarily due to high rainfall rates and high soil moisture content. A total of 17,756,000 acres of NFS land nationally have high land mass failure hazards. High water tables are the major soil management concern in the North Section, and are associated with a relatively large percentage of organic (peat and muck) soils. Nationally, a total of 8,856,000 acres of NFS land are identified with high water tables that limit management.

Management concerns and soil productivity for lands with high water table vary significantly by Section. While high water table soils often have unique management opportunities, in general, management activities are restricted by low soil strength. Managers in the North Section, with the greatest identified concern, can schedule ground-disturbing activities in winter, when the ground is frozen and the potential for detrimental soil disturbance is least. Frozen soil conditions rarely exist in the South Section; thus ground-disturbing activities are restricted to dryer seasons with increased use of specialized equipment. High water tables in the Rocky Mountain and Great Plains Sections are generally associated with stream courses. Management concerns often relate to location of roads and their effect on riparian values. The majority of limiting high water table soils in the Pacific Coast Section are located in Alaska. The relative productivity of high water table soils is low compared to upland soils in the North and Pacific Coast Sections but high in the South Section. However, the highest rangeland soil productivity values are associated with high water table soils in the Rocky Mountains and Great Plains Sections.

Surface erosion hazards affect land management in different degrees based on vegetation type and past management history. Much of the NFS land in the South Section was previously privately owned, cleared for crop production, and then abandoned before being acquired by the Government. At the time of acquisition, soil conditions were deteriorated and accelerated erosion was common. Subsequent reforestation has eliminated much of the accelerated erosion and has reversed the trend in loss of inherent soil productivity, but the high erosion potential still exists. Severe surface erosion hazards in the

Rocky Mountains and Great Plains Sections are generally associated with arid rangelands where vegetative ground cover is naturally sparse. In the Pacific Coast Section, severe erosion conditions are concentrated on the arid brush lands of California. Surface soil erosion is generally not a problem on forest lands, unless extensive ground disturbance occurs.

Land mass failure hazards affect management by reducing access to an area. Often lands with these hazards have high inherent soil productivity. Landslides in the Pacific Coast Section, on steep, moist, forested slopes, can be initiated by removal of the forest vegetation. Removal of the forest canopy, with the corresponding decrease in water transpiration by trees, often increases soil moisture content and triggers land mass failures. Hazards are often difficult to identify and evaluate in the Pacific Coast Section because of the dense forest cover. In the Rocky Mountains and Great Plains Section, land mass failure hazards are more easily identified due to the drier nature of the surrounding landscapes. Often hazard areas occupy narrow corridors or lower slope positions used for roads. In the Appalachian Mountains of the South Section, severe surface erosion hazard areas and land mass failure areas exist in close proximity.

Nationwide, about 27 million acres of NFS forest land are identified as having a high potential for soil productivity enhancement—primarily from fertilization. Also included are rangeland soils that could be improved by such practices as pitting, furrowing, and ripping.

Detrimental soil compaction and its effect on long-term soil productivity is a concern on intensively managed forest lands. On certain soils, use of mechanized equipment substantially reduces soil porosity and infiltration, which lowers productivity. The degree of impact is affected by many factors, including the type of equipment used, duration of use, soil moisture content, and existing soil condition. Detrimental soil compaction is a significant concern in the Pacific Coast and South Sections.

While broad sectional differences for soil management concerns can be identified, soil capability and productivity may vary greatly over extremely short distances. Identification of specific soil properties, combined with an understanding of basic biotic and soil processes, fosters effective resource management. The number of acres of national forest land that still need to be surveyed (called soil resource inventory needs) is shown in table 19.

Table 19.—Soil resource inventory needs (million acres) on national forest lands by section and vegetation type

Vegetation Type	Sections				Rocky Mountains and Great Plains
	All sections	North	South	Pacific Coast	
Hardwoods	0.8	0	0.4	0	0.4
Softwoods	47.2	6.1	6.8	12.2	22.1
Ranfe/Alpine/Shrub/Muskeg	21.9	0.7	0.8	1.7	18.7
Total	69.9	6.8	8.0	13.9	41.2

Source: Nordin 1987.

## CHAPTER 7: PROJECTING LAND COVER AND USE CHANGES

This chapter provides projections of changes in area for the forest and rangeland base. Area changes of the land base are important not only in terms of prospective supplies of timber, water, wildlife, and forage, but also for the intangibles such as scenery and opportunities for outdoor recreation.

Projected area changes for the resource base are described first with a national overview and then for the five major geographic sections: the North, Great Plains, South, Rocky Mountains, and the Pacific Coast. Components of the resource base—forest land, rangeland, and water areas—are the three major categories covered. Projections of area changes at the national level are the sum of regional projections from region-specific systems for projecting area change. Methods for projecting area change are discussed in more detail in Appendix A (Alig et al. 1989).

### NATIONAL OVERVIEW

Available data indicate that the area in forest and range land has been declining in recent decades (Table 20). The inland water area, on the other hand, has been increasing mainly due to reservoir construction. The relative intensity of forces affecting competition for land resources among major uses in the United States has changed notably since the last RPA Assessment in 1979. Many acres of forests and rangelands were converted to crop agriculture in the late 1970s and early 1980s, due in large part to rapid growth in agricultural exports. As with the rest of the economy, the allocation of domestic land resources is increasingly being influenced by international trade and economic conditions.

In 1950, agricultural products from about one-seventh of the cropland harvested (50 million acres) went for exports. In 1980, this had more than doubled to one-third of the harvested crop area, about 133 million acres (Raup 1980). In particular, export-driven demand for crops such as soybeans led to conversion of many acres of bottomland forest. However, the current outlook for U.S. agriculture is uncertain. Area of cropland harvested has dropped in recent years (figure 22) and recent surveys by Forest Inventory and Analysis units indicate accompanying modest gains in forest area in some states. Significant excess capacity in crop agriculture is projected, and along with related government farm programs designed to reduce cropping of highly erodible lands, this will likely reduce land use pressures on the forest and range land base (USDA Soil Conservation Service 1987).

In addition to the land use pressures exerted by crop agriculture on the forest and range land base, conversions pressures from urban and developed uses are sub-

stantial. Given recent trends and the essentially irreversibility of such conversions, the future direction of area trends in urban and developed uses appears more evident than those for agricultural uses. Studies suggest that the area in urban and developed uses will continue to grow in line with projected changes in population, personal income, and related factors (Alig and Healy 1987). The population of the U.S. is projected to increase by more than 90 million people by the year 2040, representing an increase of close to 40% (USDA Forest Service 1987).

Along with the population increase, per capita disposable personal income is projected to much more than double in constant dollar terms by 2040. Such changes will continue to fuel the expansion of urban and developed uses, and may be compounded by the overall aging of the U.S. population over the next several decades. The trend in rural versus urban growth in the 1970s and early 1980s may be changing in the latter half of the 1980s. This has important land use implications because of the differential in per capita land consumption between rural and urban uses (Alig and Healy 1987).

The total area of forest and range land is projected to increase about 2% between 1987 and 2000, and then decrease slightly by 2040. The projected increase in the forest and rangeland base by 2000 results from a 6% increase in rangeland, from 770 to 809 million acres (table 20). Between 2000 and 2040, the trend in range area is projected to be stable at around 810 million acres. The area of forest land is projected to decline over the projection period, decreasing by 4% by 2040, from 731 to 703 million acres.

The projected reduction in forest land area (table 21) will result mainly from conversion to other land uses,

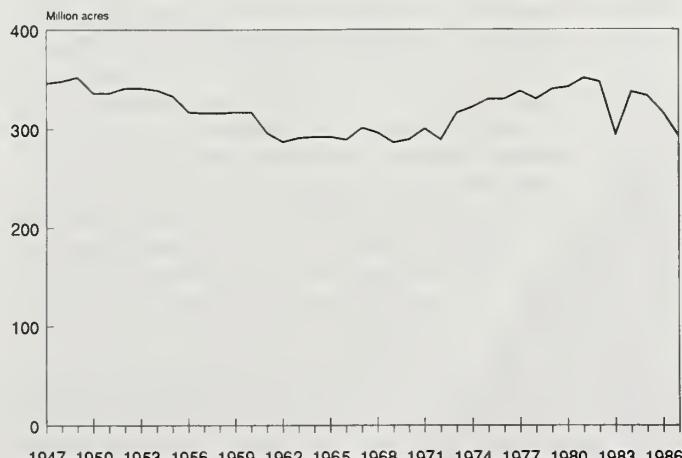


Figure 22.—Cropland area harvested in the United States, 1947-1986.

Table 20.—Land and water areas (million acres) of the United States, by class of land and water, 1970, 1977, and 1987, with projections to 2040

Class	1970	1977	1987	Projections				
				2000	2010	2020	2030	2040
<b>Land:</b>								
Forest and range land:								
Forest land <sup>1</sup>	754	737	731	718	714	710	706	703
Rangeland <sup>2</sup>	819	820	770	809	809	809	810	810
Total	1,573	1,557	1,502	1,527	1,523	1,519	1,516	1,513
Other land <sup>3</sup>	687	699	756	728	730	732	733	735
Total	2,260	2,257	2,258	2,255	2,253	2,251	2,249	2,248
Water <sup>4</sup>	105	107	107	110	112	114	116	117
Total	2,365	2,365	2,365	2,365	2,365	2,365	2,365	2,365

<sup>1</sup>Land at least 10% stocked by forest trees of any size, or formerly having such cover, and not currently developed for nontimber use. Included in these lands are transition zones, such as areas between heavily forested and nonforested lands and forest areas adjacent to urban and built-up lands, which may not have timber production as a primary use.

<sup>2</sup>Land on which the natural vegetation is predominately grasses, grasslike plants, forbs, or shrubs; and which is not currently developed for nonrange use.

<sup>3</sup>Other land includes cropland, improved pasture, industrial and urban land, and all other land categories except forest land and rangeland.

<sup>4</sup>Water area includes lakes and ponds over 2 acres in size, waterways, the Great Lakes and coastal waters and estuaries excluding Alaska and Hawaii.

Table 21.—Forest land area (million acres) in the U.S. by section, 1977, and 1987, with projections to 2040

Section	1977	1987	Projections				
			2000	2010	2020	2030	2040
<b>North and Great Plains</b>							
South	167	170	168	167	166	165	165
Rocky Mountains	209	203	198	197	195	194	193
Pacific Coast <sup>1</sup>	137	138	135	134	134	134	134
U.S. Total	224	220	217	216	214	213	211
	737	731	718	714	710	706	703

<sup>1</sup>Includes Alaska and Hawaii.

such as reservoirs, urban expansion (figure 23), highway and airport construction, and surface mining. Increased reclamation of mined lands in the future will limit the long run impacts of surface mining on the total area of forest and range land (see previous section).

The projected average annual reduction in U.S. forest area from 1987 to 2040, about 500,000 acres, is less than that for the period 1970 to 1987, which averaged approximately 1.5 million acres per year. These projections represent net area changes, and significant shifts among the uses of land at the aggregate level or more local level may underlie the small net area changes in particular uses (Healy and Short 1981).

Additions to forest land will result from tree plantings under the Conservation Reserve Program (CRP) of the 1985 Farm Bill (Moulton and Dicks 1987), which is projected to be the Nation's largest tree planting program in history. Tree plantings and reversions of CRP grassland to forest, due to natural succession, may contribute

Table 22.—Rangeland area (million acres) in the U.S. by section, 1977, and 1987, with projections to 2040

Section	1977	1987	Projections				
			2000	2010	2020	2030	2040
<b>North and Great Plains</b>							
South	78	75	91	90	89	88	86
Rocky Mountains	123	116	128	128	129	130	130
Pacific Coast <sup>1</sup>	332	339	349	349	350	350	350
U.S. Total	256	241	241	242	242	243	244
	789	771	809	810	810	811	810

<sup>1</sup>Includes Alaska and Hawaii.

5 to 10 million acres of forest land nationwide by the year 2000. Tree plantings established under an earlier related program, the Soil Bank Program of the late 1950s and early 1960s, were largely retained through the first timber rotation (Alig et al. 1980). However, such additions under the CRP and other federal and state programs are projected not to be substantial enough in acreage terms to offset conversions of forest land to urban and developed uses, and conversions of forest land to agricultural land to replace agricultural land that is developed.

The projected 5% increase in rangeland area by 2040 (table 22) will occur largely on private lands. Projections in rangeland area are based on related projected reductions in cropland area by the USDA Soil Conservation Service (1987) to reflect large excess capacity in crop agriculture in some regions and impacts of associated government programs. The largest area increases in rangeland occur by 2000 and are projected for the Rocky

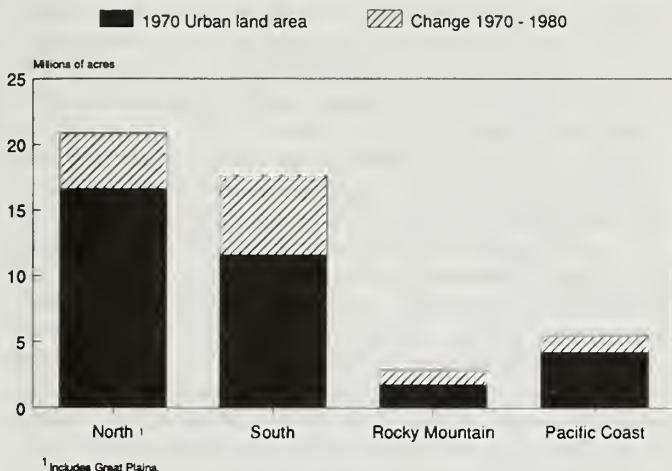


Figure 23.—Urban land area in 1970 and 1980, by region.

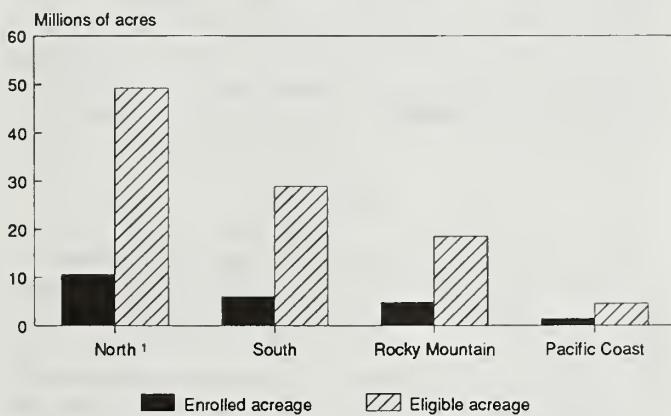


Figure 24.—Conservation reserve program acreage by region, 1986-1987.

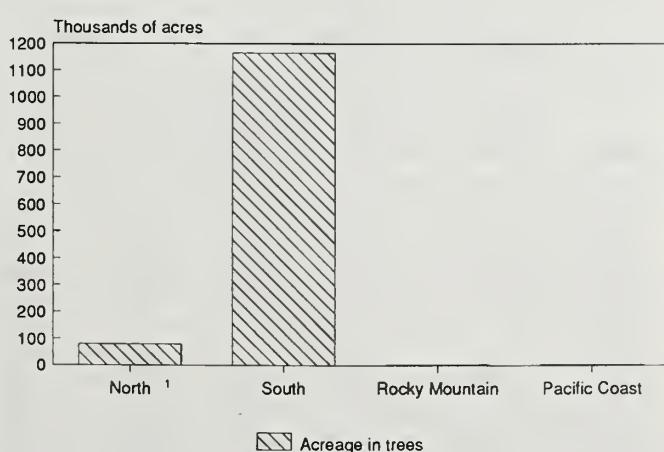


Figure 25.—Conservation reserve program acreage of trees, 1986-1987.

Mountain States, Great Plains, and Southern Plains (Texas and Oklahoma). Projected range area changes in other regions are small. The projected net gain in range area is primarily due to a reduced rate of conversion to cropland and projected acreage additions from natural reversions, due to natural succession, of grassland established under the CRP (figs. 24, 25).

Part of the uncertainty associated with the projections of land use pertain to the implementation of provisions of the 1985 Farm Bill and future farm bills. Three major provisions of the 1985 Farm Bill will likely impact future forest and range area: 1) the CRP, 2) swambuster and sodbuster provisions, and 3) the conservation compliance provision (Moulton and Dicks 1987).

Approximately 40 to 45 million acres of highly erodible land used currently for cropland are projected to be converted to grass cover or trees under the CRP by the year 2000 (USDA 1989). A large majority of the acres likely to be converted to grass cover are in the South, Great Plains, and Intermountain West. Many of these acres initially seeded to grass will gradually revert to rangeland because of natural succession.

Most southern states have substantial acreages of this highly erodible land suitable for forestation and it is assumed that over 4 million acres would be planted to trees under the CRP by the year 2000. A large majority of the trees planted under the CRP in the U.S. is expected to be in the South (figure 25).

Compared to the CRP, impacts of the "buster" and compliance provisions of the 1985 Farm Bill are more difficult to project in terms of influencing future changes in land use areas. One reason is possible changes in government commodity subsidy and loan programs that would alter the attractiveness of converting erodible land in the future. Regardless, it seems likely that the "buster" and conservation compliance provisions will have important impacts on forest and range area (Moulton and Dicks 1987). The sodbuster provision is designed to discourage farmers from converting highly erodible lands, many of which are currently in pasture or range uses, to croplands. The swambuster provision denies eligibility for farm program benefits to those who produce crops on converted wetlands. Such wetlands include bottomland hardwoods along the lower Mississippi River system, the pocosins of North Carolina, prairie potholes, and spruce permafrost in Alaska.

Over 80 million acres of existing cropland identified as highly erodible will be subject to conservation compliance. Many of such highly erodible acres will be placed under conservation practices through the CRP. As currently proposed, if farmers do not comply (i.e., implement a conservation plan or convert to a noncrop use) on highly erodible acres, they could lose government subsidies on all cropland acres. Procedures for full implementation and enforcement of provisions of the 1985 Farm Bill, such as conservation compliance, are being finalized and may be altered in the 1990 Farm Bill.

The uncertainty associated with the projections of land use in relation to the 1985 Farm Bill is heightened by the unknown contents of future national farm bills. Also some states, such as Minnesota, are adopting their own form of CRP programs.

The following pages discuss area projections by the geographic sections: the North and Great Plains, the South, the Rocky Mountains, and the Pacific Coast. Projections for three major forest ownership classes—public, forest industry, and farmer and miscellaneous private (table 23)—are discussed in more detail by Alig et al. (1989). Projections for range area change are less detailed (e.g., aggregated across ownerships) than those for forest area. The methods and assumptions used to generate the area projections are discussed in Appendix A.

## PROJECTED FOREST AND RANGE AREA CHANGES

### North and Great Plains

Total forest and range area in these sections is projected to increase (tables 21 and 22) because of increases in range area. The total forest land area in the North and Great Plains drops from about 170 million acres in 1987 to 165 million acres in 2040. Range area over the same period is projected to increase by 11 million acres or 15%.

The projections show slightly downward or fairly stable trends in many northern states. In some states such as Connecticut, Delaware, and Rhode Island, where substantial relative increases in population and economic activity are expected, the drop is fairly large. In most of the other states the projected changes are small relative to existing total forest area.

Timberland area is projected to increase in the mid-Atlantic states (New York, Pennsylvania, and West Virginia). This is linked to the changing nature of agriculture, particularly the decreases in farm area used in the dairy sector.

The distribution of forest and rangeland between private and public ownership has not changed appreciably in the last quarter of a century, and is projected to change

little over the projection period. However, considerable transfers have occurred historically among the major classes of private forest owners—farmers, forest industry, and other private owners—that comprise over 80% of the forest land base.

The area in forest industry ownership is projected to be fairly stable. This is consistent with area projections for forest industry ownership in other parts of the U.S.

The projected area in the farmer and other private group drops about 5% by 2040. As in other sections, the projected decline in nonindustrial private forest area is largely due to the continued downward trend in land owned by individuals classified as farmers. Although the CRP will convert some highly erodible cropland into tree cover, thereby augmenting the shrinking area in farm forest, the extent of expected tree planting is small relative to the existing area of farm forest.

Rangeland in the two sections is almost all in the Great Plains states, as range area in the other northern states totals less than 0.5 million acres. Range area in the North and Great Plains is projected to increase by about 16 million acres by the year 2000, due primarily to the natural succession of grassland established under the CRP (Joyce 1989). The projected trend in range area is slowly downward after 2000, resulting in a 5% drop by 2040.

### South

The land use situation in the South is relatively dynamic compared to other regions. Projected net area changes reflect the interlinked nature of the different sectors of the economy. For example, in addition to the direct conversion of forest land to urban and developed uses, other forest acres are converted to replace cropland lost to urban and developed uses (Healy 1985).

The net area of cropland is projected to drop by several million acres, while area in urban and related uses increases about 14 million acres by 2040. Pasture area is projected to drop by several million acres by 2040.

Table 23.—Area of timberland (million acres) in the United States, by ownership and section, 1952, 1962, 1970, 1977, and 1987, with projections to 2040

Ownership class and section	1952	1962	1970	1977	1987	Projections				
						2000	2010	2020	2030	2040
<b>Ownership Class</b>										
Public	153	152	150	144	136	134	134	134	133	133
Forest Industry	59	62	66	69	70	71	71	71	71	71
Farmer and other pvt.	296	304	288	278	276	270	267	263	260	257
Total, all classes	508	518	505	490	483	475	472	468	465	462
<b>Section</b>										
North and Great Plains	316	307	308	307	321	324	325	326	327	328
South	205	209	210	199	195	191	190	189	187	187
Rocky Mountain	63	63	61	57	58	56	56	56	56	56
Pacific Coast <sup>1</sup>	83	83	82	79	72	70	69	68	67	67
Total, all sections	508	518	505	490	483	475	472	468	465	462

<sup>1</sup>Includes Alaska and Hawaii.

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1.

This is due in part to an assumed steady or slight increase in demand for livestock, caused by a leveling off or decline in per capita consumption of domestic red meat along with an excess supply of forage associated with the CRP. This situation is likely to put downward pressure on income from livestock.

A slow declining trend in forest land area is projected. Total forest land area in the South is projected to drop from about 203 million acres in 1987 to 193 million acres in 2040. The projected area changes are similar for timberland, which in this section comprises about 98% of forestland. The trends represented by the projections of forest area are fairly consistent across the South. The largest area reductions are projected for states such as Florida, where substantial relative increases in population and economic activity are expected, but the reductions are smaller than ones that occurred between 1952 and 1987. In some of the other states (e.g., South Carolina), the projected area increases slightly over the latter part of the period (Alig et al. 1989).

Two major sources of uncertainty regarding future land use in the South involve the future use of the forest land with potential for use as crop, and pasture land and cropland that are highly erodible or economically suitable for pine plantations. It is difficult to predict the impact of these forces on forest area—either up or down.

About 23 million acres of timberland in the South have high or medium potential for conversion to crop land (USDA Forest Service 1988). Although this land is concentrated to some extent in the states with coastal plains, there are substantial acreages in all states. If export demands for agricultural commodities increase more than currently expected or if crop yields increase at slower rates than assumed, all or a substantial part of this area could be cleared and used for crops.

A total of 22 million acres of marginal crop and pasture land in the South, including 8 million acres of highly erodible cropland, could yield higher rates of return to owners in pine plantations (USDA Forest Service 1988). Under the existing CRP of the 1985 Farm Bill over 4 million acres of highly erodible cropland could be planted to trees by 2000. The remaining marginal crop and pasture land, distributed in fairly large acreages through most southern states, would be another logical source of land for future conservation reserve programs or for programs to increase forest resource supplies.

Alternative futures were simulated to show the effects of converting all the forest land with high or medium potential for conversion to cropland, and the effects of planting to trees all of the crop and pasture land that would yield higher rates of return in pine plantations. Either of these alternatives would have major impacts on the forest resource supply situation in the South (USDA Forest Service 1988).

Currently, approximately 90% of the South's forest land is in private ownership. This percentage has changed little since the first surveys of the South's forest resources. The land use and management decisions of these owners have greatly impacted the southern forest resource supply situation. Area changes among the major groups of owners—forest industry and other private ownerships

(which includes farmer, corporate, and other individual ownerships)—have been substantial. Around 16 million acres or 10% of the area in other private ownership has been converted to other uses or transferred to other owners, primarily forest industry, since 1952. Most of this area reduction has occurred on farmer ownerships.

Farmer ownership of forest land has declined because of several reasons. Many owners of forest land who were farm operators sold or passed on their holdings to new owners who did not secure their primary source of income from farming. In addition, many farmers increasingly secured their livelihood off farms and were subsequently classified as other individual private owners, i.e., all private owners except forest industry, farmer, and other corporate. Conversion to other uses, primarily agriculture, also has added to a reduction in farm forest area.

The timberland area in farmer ownership is projected to continue to decline by 17 million acres by 2040 (Alig et al. 1989). The projected reductions result in part from the continuing overall drop in the number of farms, caused by an economic shakedown in the farm economy. This trend is consistent across the South and in line with historical trends.

Other individual and corporate private owners have acquired many of the forest land acres that were once owned by farmers. Corporate owners include insurance companies, banks, and other institutional owners, but to be classified as such, they cannot own facilities that process timber.

Data that allow separate identification of corporate-based and other individual ownerships have been available only since 1977. Corporate private owners now hold 17 million acres of timberland in the South and have added approximately 3 million acres of this total since 1977. This acquisition was spread across all five forest management types—pine plantations, natural pine, mixed pine-hardwoods, upland hardwoods, and bottomland hardwoods—but the largest increases (over 30%) were in pine plantations and upland hardwoods (Alig et al. 1986).

Corporate ownership is projected to increase in size by approximately 7 million acres or by 40% of its current size (USDA Forest Service 1988). Part of the land is expected to be acquired through investment in southern pine timberland. As a result, pine plantation area in corporate ownership is projected to triple by 2040. It remains to be seen whether some corporate owners will divest of timberland after harvest of the current rotation's crop, or if they will invest in practices in line with long-run management of these timberlands.

Individual owners, the other component of the miscellaneous private ownership group, are the largest ownership class. This diverse set of owners hold over one-third of the southern timberland base, equal to 65 million acres. This is almost four times as much as corporate owners. Unlike the corporate class, individuals in the other private owner group are projected to reduce their holdings of timberland in the future. The projected reduction is approximately 4 million acres or 6% of the timberland area in this ownership by 2040.

Forest industry has steadily acquired timberland in the South since 1952. In 1987, industry owned 38 million acres of timberland in the South, approximately 20% more than in 1952. Most of industry's acquired acres have been in the South Central region, but the trend is upward across all the southern States.

In the past many forest products companies have found it advantageous to own large amounts of timberland. Some of the recognized advantages include an assured wood supply for mills that represent very large investments, augmentation of supplies of low-cost timber, a perceived hedge against inflation, and certain tax advantages. In addition, some banks have required certain levels of timberland to be owned as one condition for loans.

Although the latest Forestry Inventory and Analysis data do not show a significant reduction in the acquisition of timberland by industry, several factors now seem to be operating that reduce the attractiveness of industrial ownership of timberland. These include cash flow considerations, other investment opportunities in a company's portfolio, opportunities for land leasing and long term harvesting rights, and the increased substitution of more intensive forestry practices in place of land acquisition.

Given this current setting it has been assumed that the area in forest industry ownership will increase at a slower rate than in the past. Forest industries are projected to add one million acres over the next 45 years. This represents a 3% increase. Most of the acquired land is expected to be in the South Central region.

Public ownership of timberland in the South represents only about 10% of the total timberland base. Public ownership of timberland is projected to increase slightly, by 0.8 million acres or 4%, by 2040. Most of the increase is on other public ownerships (e.g., state lands), rather than national forests. Not included in the other public timberland expansion is some bottomland hardwood acreage that is likely to be acquired by state agencies and withdrawn from the timberland base to protect non-market resources.

Range area in the South is projected to increase by 14 million acres or 12% by 2040 (table 22). Approximately 97% of the rangeland in the South is in Texas and Oklahoma and competitive land use pressures between forest and range uses in the major timber growing portions of the South are relatively minor. The impacts of the CRP for range area are likely to be most important in Texas and Oklahoma. Over 10 million acres of highly erodible cropland in these states are projected to be converted to grassland by 2000. Some of this will likely revert to rangeland over the next two decades.

Land use pressures on range area from crop agriculture will also likely lessen over the projection period. The area of irrigated crop land is expected to decrease. Excess crop land in some cases will revert naturally to range cover.

### **Rocky Mountains**

Total forest and range area in this section is projected to increase by about 7 million acres, or 1.5%, by the year 2040. The increase is due to projected expansion of range area, which occurs by the year 2000. The majority of range

and forest acreage in this section is on public lands, but the projected increase in range area occurs on private lands.

Area of cropland is projected to drop by over 15 million acres, as highly erodible croplands are converted to tree and grass cover through the CRP. Area in urban and related uses is projected to increase slightly. Range area is projected to increase by several million acres. The primary reason is additions in range area from the natural succession of grass cover established under the CRP.

Projections show a slow declining trend in forest land area. The total forest land area in the Rocky Mountains drops from about 138 million acres in 1987 to 134 million acres in 2040. The projected net area changes largely reflect the direct conversion of forestland to urban and developed uses, and other acres converted for water development projects.

Overall, while future prospects are for total forest area to remain relatively stable, allocation of forest land for various uses may change (e.g., forest land may be withdrawn from timber production to protect other resource uses and values). It is likely that there will be further reductions in the area used to produce timber.

In proportion to the large number of range acres in this section—over 339 million acres—only relatively small changes in total range area are projected. The largest land use impact over the next decade will likely arise on private lands from the CRP. Over 10 million acres may be seeded to grass cover, and some of this may revert through ecological succession to range cover in subsequent years. The exact extent of such acreage will depend upon a number of factors, including possible legislative changes for the CRP, future CRP funding levels, changes in the agricultural outlook that might prompt subsequent conversion of some CRP acres back to agricultural uses after program requirements are met, and future conversion of some acres to nonagricultural uses.

### **Pacific Coast**

The projections show somewhat opposite trends for forest and range area in the Pacific Coast section. Forest area is projected to drop by 8 million acres, or 4%, by the year 2040. Range area is projected to increase by 3 million acres, or 1%, over the same period.

The projected net area changes largely reflect the direct conversion of forest land to urban and developed uses. In particular, some forest area will be converted through urban expansion near Seattle-Tacoma, numerous localities in California, and in mixed forest-urban zones in Oregon. Other forest acres are likely to be converted to replace cropland lost to urban and developed uses.

The total area of cropland and pastureland is projected to remain essentially constant. Area in urban and related uses is projected to rise, and this will also increase the forested area that is intermingled with areas developed for nonforest use (Oswald 1984).

Area changes among the major groups of owners—forest industry and other private ownerships (which includes farmer, corporate, and other individual ownerships)—have been substantial. Around 5 million acres or 28% of the timberland area in farmer and other private ownership has been converted to other uses or transferred to other owners since 1952. Most of this area reduction has occurred on farmer ownerships.

Currently, industry owns approximately 23% of the Pacific Coast timberland, up from an 18% share in 1952. The area in forest industry ownership is projected to be fairly stable. Changes in how forestland is managed are likely to be more important than area changes for this ownership. As in other parts of the U.S., increasing amounts of timberland formerly owned by companies that operated mills are now owned by corporations who do not operate mills.

Projected reductions in farm forest area result in part from the continuing overall drop in the number of farms, caused by an economic slowdown in the farm economy. This trend is consistent across the U.S. and in line with historical trends.

Other individual and corporate private owners have acquired many of the timberland acres that were once owned by farmers. Corporate ownership is projected to increase in size. Part of the land is expected to be acquired through investment in timberland growing Douglas fir.

Area changes are projected to occur slowly here, compared to regions in the East. Much of the timberland is located on lands where forestry has a strong comparative advantage or is a residual use. Legislation in this region affecting land use practices is designed in part to promote stability of the private timberland base.

No major shifts among major land uses in Alaska are projected through 2040. Total area in forest and rangeland is projected to remain fairly constant, although further ownership changes are likely. Although total forest land area is projected to remain close to current levels, projected exchanges among ownerships include an additional 0.2 million acres of national forest land to be transferred to the state and 0.3 million acres to Alaska Native ownership, now classified as farmer and other private. Forest industry ownership is expected to remain negligible, although in time part of the land transferred to Alaskan Natives may be sold to forest industries.

The small projected increase in range area in the Pacific Coast Section occurs in California, Oregon, and Washington. Some range acres may be added through reversion of CRP grassland acres, due to natural succession, primarily in eastern Oregon and eastern Washington. The rate of conversion of brushlands to open grazing lands has decreased in California, due in large part to limitations on the use of prescribed fire.

### PROJECTED AREA CHANGES FOR FOREST TYPES

#### North and Great Plains

Recent trends in area changes for forest types in these sections are projected to largely continue. The largest area change for forest types in the North and Great Plains is

projected for northern hardwoods (figure 26), which increases by several million acres by 2040. This forest type is comprised of the climax and shade-tolerant maple-beech-birch, which is projected to increase because of successional forces. Sugar maple and yellow birch are important components of this type. The area in red maple is likewise expected to increase, particularly in the Northeast.

Conversely, oak-hickory area is projected to drop slowly. The forests of the North, being relatively diverse, are forests in transition. Reduction of wildfire is affecting area changes among types, and will continue to push the succession of oak forests to other species. Selective cutting has increased the dominance of sugar maple. Also adding to the projected drop in oak-hickory area is the conversion of such stands for the management of softwoods. However, the associated projected change is small because much of the land is held by nonindustrial private landowners who do not manage their forest stands intensively.

Area in aspen-birch area is also projected to drop slightly. The area in aspen-birch is sensitive to disturbances because it is a pioneer type. Therefore, the area of aspen-birch has been declining because most stands have not been intensively managed in the past. The rate of area loss is projected to slow because more stands are likely to be clearcut for panel production.

The area in softwood types is projected to be fairly stable over the projection period. Spruce-fir may decline slightly due to harvesting pressures, the increased use of clearcutting and environmental factors. The area in white-red-jack pine is also projected to drop slightly, and oak-pine is projected to gain in some cases at the expense of the white pine. The area in pitch-loblolly-shortleaf is expected to decline. Hemlock area is projected to increase due to natural succession in conjunction with lack of management on the extensive nonindustrial private lands.

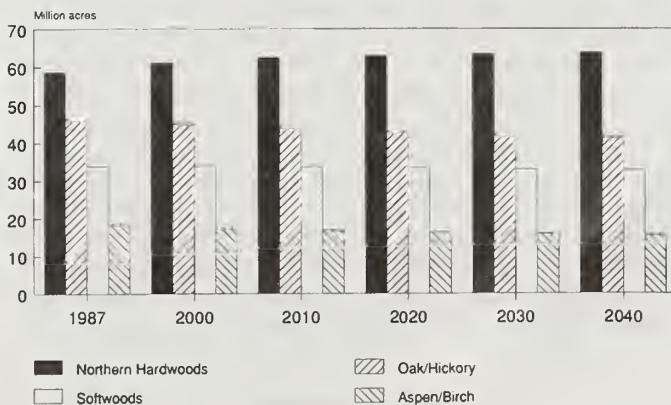


Figure 26.—Timberland area in the North, by forest type, 1987, with projections to 2040.

In both the North Central and Northeast regions, projected area changes for forest types are largely based on a continuation of recent trends (Spencer et al. 1988). Area for forest types in the Great Plains were projected in conjunction with those for the North Central region because of the similarity in forest types. The overall existing distribution among forest types is projected to change little over the projection period.

### South

Projected changes in the area of the forest types in the South are consistent with recent historical trends (fig. 27). The largest area changes are projected for the pine types in the South, which represent some of the largest and most important area changes for forest types in the U.S. The area in pine plantations is projected to go up by approximately 22 million acres, thereby doubling by 2040. In contrast, natural pine area is projected to drop by 20 million acres or nearly half.

The net change in southern pine area is an increase of approximately three million acres by 2040. The projected doubling of planted pine area is largely due to the addition of pine plantations on forest industry lands. In addition, about 4 million acres of planted pine may be added through the CRP on nonindustrial private lands by the year 2000.

With management intensification on industrial lands, many harvested natural pine stands are being artificially regenerated. This conversion to planted pine allows genetically improved stock to be introduced on many acres and trees to be spaced in a manner which reduces the cost of subsequent industrial operations. The projected drop in natural pine area is also due to an assumed continuation of trends in substantial hardwood encroachment after harvest of pine stands on lands in other private ownerships (USDA Forest Service 1988). The other private ownerships contain the bulk of the natural pine area, and the projections assume that current trends in reforestation will largely continue.

Hardwood area in the South is projected to drop by about 10% by 2040. Several reasons for this projected decline include conversion of upland hardwood area to pine, especially on industrial lands; conversion of timberland on farms to cropland; and conversion of upland hardwood acreage to urban and developed uses.

Area in oak-pine or mixed pine-hardwood is projected to drop by over 6 million acres or about one-fifth of the existing area in this type. Much of this reduction occurs on forest industry lands, where many acres are converted to pine types. It should be noted that oak-pine is a relatively unstable type since it represents an intermediate stage in natural successional trends.

### Rocky Mountains

Analysis of historical data indicated relatively slow exchanges among major groupings of forest types on a regional scale. Disturbances in forest stands are relatively infrequent in this section compared to other sections.

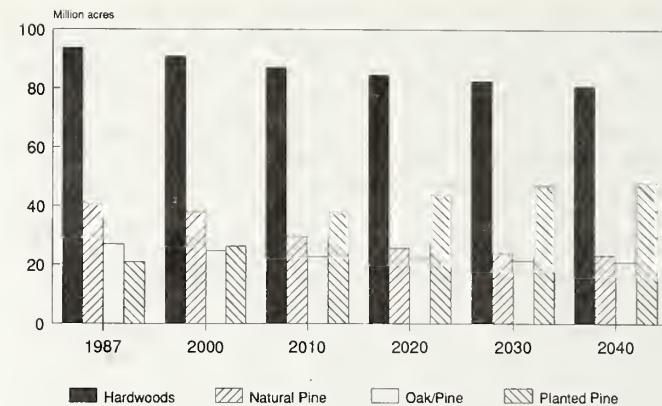


Figure 27.—Timberland area in the South, by forest type, 1987, with projections to 2040.

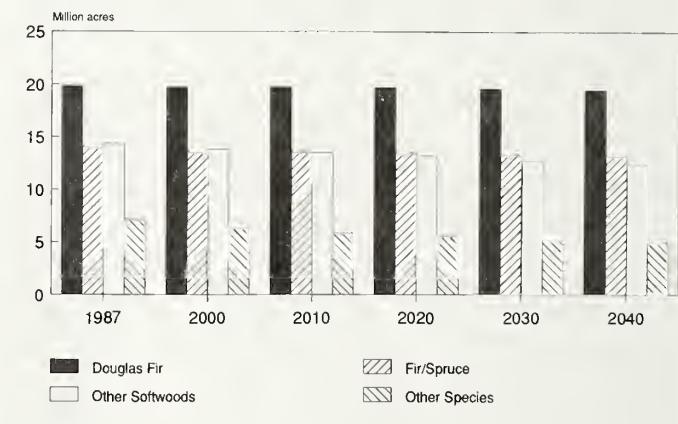


Figure 28.—Timberland area in the PNW Douglas fir region by forest type, 1987, with projections to 2040.

Forest land in the Rocky Mountain section was classified into hardwood and softwood types independent of the ownership class. Species-specific timber types were aggregated into hardwood and softwood types and used to compute the proportion of the forest land area in hardwood and softwood types. These proportions were projected to be the same in each decade between the years 2000 and 2040. In each decade, the timber type proportions were multiplied times the projected forest land area to obtain estimates of area by hardwood and softwood types.

### Pacific Coast

Overall, projected net area changes for forest types in the Pacific Coast section are relatively small (figure 28). The most substantial changes are projected to occur on forest industry lands, as more acres are planted to Douglas-fir.

Hardwood area on the forest industry ownership is projected to decline. If recent stumpage price increases

for alder continue, the rate of alder conversion may lessen. Alder frequently becomes established after softwood harvests on other ownerships and its acreage has recently increased in some areas in western Oregon and Washington.

One management decision likely to continue is to allow more western hemlock to regenerate naturally, including mixtures of Douglas fir and western hemlock. Other trends discussed in the Pacific Coast section that are likely to continue in the foreseeable future include an increase in hardwoods in some coastal areas where conifers are harvested. In the interior, tolerant species such as white fir and incense cedar may increase as pines are removed from mixed conifer stands.

The projected drop in the area of "other softwoods" primarily involves ponderosa and lodgepole pine. Many of these acres are in eastern Oregon and Washington. The projections are based on a continuation of recent trends.

Projected timberland losses on farmer and miscellaneous private lands are distributed across all forest types. This is also the case for other public lands.

### PROJECTED CHANGES BY SITE CLASS AND OTHER PRODUCTIVITY IMPACTS

Site, a measure of the inherent capacity of land to grow trees, is one of the important determinants of changes in the forest resource. However, analysis of data first assembled around the mid-1960s for the South (one of the major timber growing regions and probably the most dynamic in terms of land base changes), indicates there have been no major net changes in the regional distribution of timberland by site class. For example, the last two surveys in the Southeast indicate that overall there have been only relatively minor shifts in the proportions of area by site class, toward the higher classes.

Based on the analysis of historical site data for the South and the general lack of data indicating otherwise for other sections, it was assumed in this study that the distribution of timberland among the site classes would not change significantly over the projection period. It should be noted that trends may vary in localized areas. Investments in intensive management can alter the inherent productivity in many cases. In the South the conversion of many forest acres to pine plantations implies a shift toward a higher site class. An example is the upgrading of substantial acreages of low productivity land in the coastal plain that are being drained, site prepared, bedded, and planted to pine.

Projected changes in rangeland condition classes (see Chapter 1) and related questions are discussed along with an analysis of the forage resource in a supporting RPA document (Joyce 1989). No major changes are projected.

Another consideration when examining the future productivity of forest and rangelands is the continued spread of "irreversible" developed or built-up uses over the rural landscape. In recent decades, this has led many observers to wonder about the degree to which their

expansion was affecting the availability of land for agricultural and forestry commodity production and for recreation. Hence, the growing attention paid to the "urban-rural interface" and associated forest and rangeland management questions. Bureau of the Census statistics for the first half of the 1980s indicate a reversal of the relative rural growth pattern of the 1970s. However, physical occupation of the land base by built-up uses is projected to remain well below 10% over the next several decades for the U.S. (Alig and Healy 1987).

Expansion of built-up uses into rural areas has other important impacts besides the actual conversion of forest and rangeland. Expectations of neighboring landowners about the future use of their land may be influenced, generally reflected in higher asking prices for land. Property taxes may also rise, reflecting the new, higher land values. Composition of landownership may change, with an increasing proportion of landowners being primarily nonfarmers, although the land may still be used for farming, often on a rental basis. In addition, as expectations about future urban uses rise, land is typically divided into smaller parcels. This can have profound impacts on the economics of forestry, even when the land is not physically altered in any major way (Healy and Short 1981). Little information exists regarding the amount of higher quality forest and rangeland that may be converted to built-up uses. There are also "juxtaposition effects"—spatially bounded externalities that affect adjoining or nearby land (Healy 1985). These effects may be either positive (e.g., a new reservoir raises recreational attractiveness of nearby forest land) or negative (e.g., new residents object to spraying of herbicides or to clearcuts or controlled burns on forest land) (Bradley 1984).

Existing urbanization measures also provide little information on the extent to which many nonresidential lands, for which site improvements occupy only a small portion of relatively large tracts, are classified as built-up. For example, rural industrial plants and associated improvements (e.g., parking lots) often occupy 10% or less of their sites, with the remainder often in forest or range cover. Open portions of developed sites are seldom used for commodity production but may be available for such use should future demand warrant it.

Another consideration in the long-term outlook for changes in forest area is the implications of changing climate. Possible climate change is a less than certain issue, but it has important implications in terms of impacts on forest growth (Rose et al. 1987) and possible changes in total forest area, as well as the relative distribution of forest types. There is much ongoing related research and monitoring of the possible effects, and this should assist in assessing its importance along with the other factors that influence forest area changes.

### REFERENCES

Abelson, Philip H. 1987. Energy futures. *American Scientist*. 75:584-592.

Aldon, Earl F.; Loring, Thomas J.; tech coords. 1977. Ecology, uses, and management of pinyon-juniper woodlands. In: Proceedings of the workshop; 1977 March 24-25; Albuquerque, NM. Gen. Tech. Rep. RM-39. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 48 p.

Alexander, Robert R. 1985. Major habitat types, community types, and plant communities in the Rocky Mountains. Gen. Tech. Rep. RM-123. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 105 p.

Alig, Ralph J. 1985. Modeling area changes in forest ownerships and cover types in the Southeast. Res. Pap. RM-260. Ft. Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 18 p.

Alig, Ralph J. 1986. Econometric analysis of forest acreage trends in the Southeast. *Forest Science* 32(1):119-134.

Alig, Ralph J.; Healy, Robert G. 1987. Urban and built-up land area changes in the United States: An empirical investigation of determinants. *Land Economics* 63(3): 215-226.

Alig, Ralph J., Knight, Herbert A.; Birdsey, Richard A. 1986. Recent area changes in southern forest ownerships and cover types. Res. Pap. SE-260. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 10 p.

Alig, Ralph J.; Mills, Thomas J.; Shackelford, Robert L. 1980. Most Soil Bank plantings in the South have been retained: Some need follow-up treatments. *Southern Journal of Applied Forestry* 4:60-64.

Alig, Ralph J.; Murray, Brian; Hohenstein, Murray; Haight, Robert. 1989. Changes in timberland area in the United States by State and ownership, 1952-1987, with projections to 2040. USDA Forest Service, General Technical Report (SE-in process). Asheville, NC.

Alig, Ralph J.; White, Fred C.; Murray, Brian C. 1988. Economic factors influencing land use changes in the South Central United States. USDA Forest Service Research Paper SE-272. Southeastern Forest Experiment Station. Asheville, NC. 23 p.

Alig, Ralph J.; Wyant, James G. 1985. Projecting regional area changes in forestland cover in the U.S.A. *Ecological Modeling* 29:27-34.

Argonne National Laboratory 1988. An assessment of the natural gas resource base of the United States. Washington, D.C.: U.S. Department of Energy. 126 p.

Arno, Stephen F.; Gruell, George E. 1986. Douglas-fir encroachment into mountain grasslands in southwestern Montana. *Journal of Range Management*. 39: 272-276.

Bailey, Robert G. 1978. Ecoregions of the United States. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 77 p. and map.

Barbour, M. G; Major, Jack; eds. 1977. Terrestrial vegetation of California. New York: John Wiley and Sons, Inc. 1002 p.

Barchet, W.R. 1987. Acidic deposition and its gaseous precursors. In: NAPAP Interim Assessment, Vol. III: Atmospheric Processes and Deposition. Washington, DC: National Acid Precipitation Assessment Program: 5-i-5-116.

Barrett, John W. 1980. Regional silviculture of the United States. Second Edition. John Wiley and Sons. 551 p.

Bartolome, James W. 1983. Overstory-understory relationships: lodgepole pine forests. In: Bartlett, E.T.; Betters, David R., eds. Overstory-understory relationships in western forests. Western Regional Research Publication No. 1. Fort Collins, CO: Colorado State University, Agricultural Experiment Station: 1-4.

Bedell, Thomas E.; coord. 1985. Western juniper management. In: Proceedings of the short course: 1984 October 15-16; Bend, OR. Oregon State University, Corvallis, Or. 98 p.

Berck, Peter; Parks, Peter J. 1987. Modeling the western forest land base: An approach based on economic efficiency. Final report for Cooperative Agreement between University of California at Berkeley, Pacific Northwest Forest and Range Experiment Station, and Southeastern Forest Experiment Station. On file at USDA Forest Service Southeastern Forest Experiment Station, Research Triangle Park, NC.

Betters, David R. 1983. Overstory-understory relationships: aspen forests. In: Bartlett, E.T.; Betters, David R., eds. Overstory-understory relationships in western forests. Western Regional Research Publication No. 1. Fort Collins, CO: Colorado State University, Agricultural Experiment Station: 5-8.

Blaisdell, J. P.; Murray, R. B.; McArthur, E. Durant. 1982. Managing Intermountain rangelands—sagebrush-grass ranges. Gen. Tech. Rep. INT-134. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 41 p.

Bradley, Gordon A., ed. 1984. Land use and forest resources in a changing environment: The urban/forest interface. Seattle: University of Washington Press.

Branson, Farrel A. 1985. Vegetation changes on western rangelands. Range Monograph No. 2. Denver, CO: Society for Range Management. 76 p.

Braun, E. L. 1964. Deciduous forests of eastern North America. New York; Hafner Publishing Co. 596 p.

Buck, Michael. 1987. Ecosystems, The Hawaiian Islands. Unpublished paper. Hawaii Division of Forestry and Wildlife, Honolulu. 2 p.

California Department of Forestry. 1987. Trends and future of rangelands: the 1987 FRRAP Assessment. Sacramento, CA: California Department of Forestry.

Clary, Warren P. 1983. Overstory-understory relationships: Spruce-fir forests. In: Bartlett, E.T.; Betters, David R., eds. Overstory-understory relationships in western forests. Western Regional Research Publication No. 1. Fort Collins, CO: Colorado State University, Agricultural Experiment Station: 9-13.

Clary, Warren P. 1987. Herbage production and livestock grazing on pinyon-juniper woodlands. In: Everett, Richard L., comp. Proceedings—Pinyon-juniper conference; 1986 January 13-16, Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station: 440-447.

Conrad, C. Eugene; Oechel, Walter C.; tech coords. 1982. Dynamics and management of Mediterranean-type ecosystems. In: Proceedings of the symposium; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 637 p.

Council on Environmental Quality. 1981. Regulation of surface mining and reclamation of minerals other than coal. Washington, DC: Council on Environmental Quality. 65 p.

Council on Environmental Quality. 1985. Environmental Quality 1985: 16th Annual Report of the Council on Environmental Quality. 446 pages. Government Printing Office, Washington, DC.

Cowardin, L.M.; Carter, V.; Golet, F.C.; LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats in the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. 103 pp.

Crawford, Hewlette S.; Porter, Ivan R. 1974. Upland hardwood-bluestem range. In: Lewis, Clifford E.; Grelan, Harold E.; White, Larry D.; Carter, Clifford W. Range resources of the South. Georgia Agricultural Experiment Station Bulletin N.S. 9. Tifton, GA: University of Georgia, College of Agriculture, Coastal Plain Experiment Station: 17-19.

Croker, Thomas Caldwell, Jr. 1987. Longleaf pine-a history of man and a forest. Forestry Report R8-FR7. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 37 p.

DeGraaf, Richard M; Rudis, Deborah D. 1986. New England wildlife: habitat, natural history, and distribution. Gen. Tech. Rep. NE-108. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 491 p.

Dunlap, L.C.; Lyon, J.S. 1986. Perspectives on the effectiveness of SMCRA: environmental. West Virginia Law Review. 88(3): 547-559.

Evans, Keith E.; Kirkman, Roger A. 1981. Guide to bird habitats of the Ozark Plateau. Gen. Tech. Rep. NC-68. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 79 p.

Everett, Richard L. 1987. Plant response to fire in the pinyon-juniper zone. In: Everett, Richard L., comp. Proceedings—Pinyon-juniper conference; 1986 January 13-16, Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station: 152-158.

Eyre, F. H. ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 148 p.

Fennemann, Nevin M. 1938. Physiography of Eastern United States. First Edition. New York and London: McGraw-Hill Book Company, Inc. 714 p.

Fisher, W.L. 1987. Can the U.S. oil and gas resource base support sustained production? Science 236: 1631-1635.

Flather, C. F. [In press]. An assessment of the wildlife resources of the United States. Gen. Tech. Rep. WO-00. Washington, DC: U.S. Department of Agriculture, Forest Service.

Franklin, Jerry F.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 417 p.

Frayer, W.E.; Monahan, T.J.; Bowden, D.C.; Graybill, F.A. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's and 1970's. Dept. of Forest and Wood Sciences, Colorado State University, Ft. Collins. 32 pp.

Frey, Thomas H.; Hexem, Roger. 1985. Major uses of land in the United States: 1982. Economic Research Service Ag. Econ. Report No. 535. Washington, DC; GPO. 29 p.

Galt, Dee. 1988. Nonfederal rangeland resources for the Pacific Coastal States. Unpublished paper. Department of Agriculture, Soil Conservation Service, Portland, OR. 11 p.

Garrison, George A.; Bjstad, Ardell J.; Duncan, Don A.; Lewis, Monte E.; Smith, Dixie R. 1977. Vegetation and environmental features of forest and range ecosystems. Agric. Handb. 475. Washington, DC: U.S. Department of Agriculture, Forest Service. 68 p.

Gasser, Don. coord. (in press). Growing wood for 21st century markets. In: Proceedings of the symposium; 1987 April 30-May 1; South Lake Tahoe, NV. University of California Cooperative Extension, Berkeley, CA.

General Accounting Office. 1986. Surface mining: difficulties in reclaiming mined lands in Pennsylvania and West Virginia. Washington, DC: General Accounting Office. 70 p.

Green, Alan W.; VanHooser, Dwane D. 1983. Forest Resources of the Rocky Mountain States. Resour. Bull. INT-33, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 127 p.

Grelan, Harold E. 1978. Forest grazing in the South. Journal of Range Management. 31:244-245.

Gruell, George E. 1983. Fire and vegetative trends in the Northern Rockies: Interpretations from 1871-1982 Photographs. Gen. Tech. Rep. INT-158. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 117 p.

Gueritte-Voegelein, Francoise; Guenard, Daniel; Potier, Pierre. 1987. Taxol and derivatives: a biogenetic hypothesis. Journ. of Natural Products. 50(1):9-18.

Halls, Lowell K.; Schuster, Joseph L. 1965. Tree-herbage relations. Journal of Forestry. 63:282-283.

Hamilton, Robert B.; Yurkunas, Vincent G. 1987. Avian use of habitats in the longleaf-slash pine forests of Louisiana. In: Pearson, Henry A.; Smiens, Fred E.; Thill, Ronald E., comp. Ecological, physical, and socioeconomic relationships within southern National Forests: Proceedings of the Southern Evaluation Project workshop; 1987 May 26-27; Long Beach, MS. Gen. Tech. Rep. SO-68. New Orleans, LA U.S. Department of Agriculture, Forest Service, Southern Exp. Sta.: 125-131.

Hargreaves, D.; Fromson, S. 1983. World index of strategic minerals: production, exploitation, and risk. New York, NY: Facts on File, Inc. 300 p.

Haynes, R. W. [In press] An analysis of the timber situation in the United States: 1989-2040. General Technical Report WO-OO. Washington, DC: U.S. Department of Agriculture, Forest Service.

Healy, Robert G.; Short, James L. 1981. The market for rural land: trends, issues, problems. Washington, D.C.: The Conservation Foundation.

Healy, Robert G. 1985. Competition for land in the American South: agriculture, human settlement, and the environment. Washington, DC: The Conservation Foundation, 334 p.

Heimlich, Ralph. 1985. Sodbusting: Land use changes and farm programs. Agricultural Economic Report No. 536. Washington, DC: U.S. Department of Agriculture, Economic Research Service. 28 p.

Hewitt, George B.; Onsager, Jerome A. 1983. Control of grasshoppers on rangeland in the United States—a perspective. *Journal of Range Management*. 36:202-207.

Honig, R.A.; Olson, Richard J.; Mason, W. T. 1981. Atlas of coal/minerals and important resource problem areas for fish and wildlife in the conterminous United States. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service. 42 p.

Howard, Theodore; Lutz, Jack. 1989. Land use and forest ownership changes in the Northeast. Department of Forest Resources. University of New Hampshire, Durham. Forest Resources Manuscript 426. 36 p.

Hunt, Francis A. 1986. National register of big trees. *American Forests* 92(4): 21-52.

Huszar, Paul C.; Young, John E. 1984. Why the great Colorado plowout? *Journal of Soil and Water Conservation*. 39:232-234.

Johnson, J.; Paone, J. 1982. Land utilization and reclamation in the mining industry, 1930-80. Information circular 8862. Washington, DC: U.S. Department of Interior, Bureau of Mines. 22 p.

Johnston, Barry C. 1987. Plant associations for Region Two. Rocky Mountain Region R2-ECOL-87-2. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region. 429 p.

Joyce, Linda. 1989. An analysis of the forage situation in the United States: 1989. USDA Forest Service, General Technical Report WO—in process. Fort Collins, CO.

Joyce, Linda A.; Skold, Mel D. 1988. Implications of changes in the regional ecology of the Great Plains. In: Mitchell, John E.; Winlor, Richard The Conservation Reserve Symposium; 1987 September 16-18, Denver, CO. Gen. Tech. Rep. RM-158. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 32 p.

Kantrud, H. A. 1982. Maps of distribution and abundance of selected species of birds on uncultivated native upland grasslands and shrubsteppe in the Northern Great Plains. FWS/OBS-82/31. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service. 31 p.

Klopatek, Jeffrey M.; Olson, Richard M.; Emerson, Craig J.; Honess, Jan L. 1979. Land-use conflicts with natural vegetation of conterminous United States. American Geographical Society Special Publication No. 36. New York, NY: American Geographical Society. 1 map-sheet [ 116 p. manual, scale—1:3,168,000.

Knight, Herbert A. 1987. The pine decline. *Jour. For.* 85:25-28.

Kuchler, A. W. 1964. Potential natural vegetation of coterminous United States. American Geographical Society Special Publication No. 36. New York, NY: American Geographical Society. 1 map-sheet, scale 1:3,168,000, 116 p. manual.

Lamb, Samuel H. 1981. Native trees and shrubs of the Hawaiian Islands. Sunstone Press, Santa Fe, NM. 159 p.

Lansberg, Hans H. 1987. Rethinking energy security: the case for coal in the United States. *Environment*. 29(6):19-20, 38-43.

Leopold, A. Starker; Gutierrez, Ralph J.; Bronson, Michael T. 1981. North American game birds and mammals. New York, NY: Charles Scribner's Sons. 198 p.

Leshy, John D. 1987. The mining law: a study in perpetual motion. Washington, DC: Resources for the Future. 521 p.

Martin, S. Clark. 1975. Ecology and management of southwestern semidesert grass-shrub ranges: The status of our knowledge. Research Paper RM-156. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 39 p.

Mauk, Ronald L.; Henderson, Jan A. 1984. Coniferous forest habitat types of northern Utah. Gen. Tech. Rep. INT-170. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 89 p.

McArthur, E. Durant; Plummer, A. Perry; Davis, James N. 1978. Rehabilitation of game range in the salt desert. In: Wyoming shrublands: Proceedings of the seventh Wyoming shrub ecology workshop; 1978 May 31-June 1, Rock Springs, WY. Laramie, WY: University of Wyoming Agricultural Experiment Station: 23-50.

McNicholas, Helen L., ed. 1983. Alaska's agriculture and forestry. Alaska Rural Development Council Pub. No. 3. Fairbanks, Alaska: University of Alaska, Cooperative Extension Service. 220 p.

McWilliams, William, H.; Birdsey, Richard A. 1983. Loblolly pine ecosystem of the midsouth. In: Proceedings of the symposium on the loblolly pine ecosystem (West Region). 1983 March 20-23; Jackson, MS: 41-58.

McWilliams, William H.; Sheffield, Raymond M.; Hansen, Mark H.; Birch, Thomas W. 1986. The shortleaf pine resource. In: Proceedings of the symposium on the shortleaf pine ecosystem. 1986 March 31-April 2; Little Rock, AR: 9-23

McWilliams, William, H.; Birdsey, Richard A. 1987. Midsouth timber statistics. *Resour. Bull. SO-108*. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 42 p.

Mitchell, John. 1983. Overstory-understory relationships: Douglas-fir forests. In: Bartlett, E. T.; Betters, David R., eds. Overstory-understory relationships in western forests. Western regional Research Publication No. 1. Fort Collins, CO: Colorado State University Experiment Station: 27-34.

Mitchell, John; Joyce, Linda A. 1986. Use of a generalized linear model to evaluate range forage production estimates. *Environmental Management*. 10:403-411.

Moulton, Robert; Dicks, Michael. 1987. Implications of the Food Security Act of 1985 for forestry: The sleeping giant. pp. 163-176, In proceedings of the 1987 Joint Meeting Southern Forest Economics Workers and Midwest Forest Economists. 1987 April 8-10, Asheville, NC.

Mullin, Keith; Williams, Kenneth L. 1987. Mammals of Longleaf-slash pine stands in central Louisiana. In: Pearson, Henry A.; Smiens, Fred E.; Thill, Ronald E., comp. Ecological, physical, and socioeconomic relationships within southern National Forests: Proceedings of the Southern Evaluation Project Workshop; 1987 May 26-27, Long Beach, MS. Gen. Tech. Rep. SO-68. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 121-124.

National Acid Precipitation Program. 1987. Interim assessment. Office of Research. Washington, DC. Volumes 1-4.

National Research Council. 1979. Surface mining of non-coal minerals. Washington, DC: National Academy of Sciences. 339 p.

Nordin, John. 1987. Unpublished notes on National Soil Management Concerns. On file with Watershed and Air Management; Washington, DC: U.S. Department of Agriculture, Forest Service.

Odum, William E.; McIvor, Carole C.; Smith, III, Thomas J. 1982. The ecology of the mangroves of South Florida: A community profile. FWS/OBS-81/24. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services. 144 p.

Oswald, Daniel D. 1984. Timber resource in areas developed for nonforest uses in western Washington. *Resour. Bull. PNW-112*. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p.

Parks, Peter J.; Alig, Ralph J. 1988. Land base models for forest resource supply analysis: A critical review. *Canadian Journal of Forest Research* 18:965-973.

Parks, Peter J. 1986. The influence of economic and demographic factors on land use decisions. PhD dissertation, University of California, Berkeley. 85 p.

Parks, Peter J. 1988a. A linear proportions model for private timberland in the West. Southeastern Center for Forest Economics Research Working Paper No. 52, Research Triangle Park, NC.

Parks, Peter J. 1988b. Forest type projections for the Lake States. Southeastern Center for Economics Research Working Paper No. 53, Research Triangle Park, NC.

Parks, Peter J. 1988c. Projecting area changes for forest types in the Pacific Northwest. Final report for Cooperative Research Agreement 29-111, on file at the USDA Forest Service, Southeastern Forest Experiment Station. Research Triangle Park, NC.

Paulsen, Jr. Harold A. 1975. Range management in the Central and Southern Rocky Mountains: a summary of the status of our knowledge by range ecosystems. *Res. Pap. RM-154*. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 34 p.

Pfister, R. D.; Kovalchik, B. L.; Arno, S. F.; Presby, R. C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

Phillips, Douglas, R.; Abercrombie, James A., Jr. 1987. Pine-hardwood mixtures-a new concept in regeneration. *Southern Journal of Applied Forestry*. 11(4): 192-197.

Pieper, Rex D.; Anway, Jerry C.; Ellstrom, Mark A.; Herbel, Carlton H. 1983. Structure and function of North American desert grassland ecosystems. Special Report 39. Las Cruces, NM: New Mexico State University, Agricultural Experiment Station. 298 p.

Plantinga, Andrew; Buongiorno, Joseph; Alig, Ralph J.; Spencer, John S. Jr. 1989. Timberland area change in the Lake States: Past trends, causes, and projections. NC Research Paper -in press. USDA Forest Service, North Central Experiment Station, St. Paul, Minnesota.

Powell, Douglas S.; Kingsley, Neal P. 1980. The forest resources of Maryland. *Resour. Bull. NE-61*. Broome, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 103 p.

Raup, Philip M. 1980. Competition for land and the future of American agriculture. pp. 41-77, In: *The Future of American Agriculture as a Strategic Resource*, edited by Sandra S. Batie and Robert G. Healy. The Conservation Foundation. Washington, D.C.

Risser, P. G.; Birney, E. C.; Blocker, H. D.; May, S. W.; Parton, W. J.; Wiens, J. A. 1981. The true prairie ecosystem. US/IBP Synthesis Series 16. Stroudsburg, PA: Hutchinson Ross Publishing Co. 557 p.

Roe, H.B.; Ayres, Q.C. 1954. Engineering for agriculture drainage. McGraw-Hill Book Co., New York. 501 pp.

Romm, Jeff; Tuazon, Raul; Washburn, Court; Bendix, Judy; Rinehart, James. 1983. The non-industrial forestland owners of northern California. Department of Forestry and Resource Management, University of California, Berkeley, CA. n.p.

Rose, D.W., Ek, A.R.; Belli, K.L. 1987. A conceptual framework for assessing impacts of carbon dioxide change on forest industries. In: *The greenhouse effect, climate change, and U.S. forests*. The Conservation Foundation, pp.259-275.

Rosson, James F. Jr.; Doolittle, Larry. 1987. Profiles of midsouth nonindustrial private forests and owners. *Resour. Bull. SO-125*. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 39 p.

Rudis, Victor A.; Birdsey, Richard A. 1986. Forest resource trends and current conditions in the lower Mississippi Valley. *Resour. Bull. SO-116*, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 7 p.

Rowntree, Rowan A. 1987. Contemplating the urban forest. In: *Our American land*. 1987 Yearbook of Agriculture. U.S. Government Printing Office, Washington, D.C. pp. 126-130.

Salwasser, Hal. 1987. Spotted Owls: turning a battle-ground into a blueprint. *Ecology*. 68:776-779.

Schmidt, John L.; Gilbert, Douglas L., eds. 1978. *Big game of North America, ecology and management*. Harrisburg, PA: Stackpole Books. 494 p.

Shaw, S.P.; Fredine, C.G. 1971. *Wetlands of the United States*. U.S. Department of Interior, Fish and Wildlife Service Circ. 39.

Sheffield, Raymond M.; Knight, Herbert A. 1982. Loblolly pine resource-southeast region. In: *Proceedings of the symposium on the loblolly pine ecosystem (East Region)*. 1982 December 8-10: Raleigh, NC: 7-23.

Sheffield, R.M.; Knight, H.A.; McClure, J.P. 1983. The slash pine resource. In: *Proceedings of the managed slash pine ecosystem*. 1983 June 9-11: Gainesville, FL: 4-23.

Shelford, Victor E. 1963. *The ecology of North America*. Urbana, IL: University of Illinois Press. 609 p.

Short, Henry L. 1983. Wildlife guilds in Arizona desert habitats. *Tech. Note* 362, Washington, DC: U.S. Department of Interior, Bureau of Land Management. 258 p.

Simberloff, Daniel. 1987. The Spotted Owl fracas: mixing academic, applied, and political ecology. *Ecology*. 68:766-771.

Spang, Edward F. 1987. Multiple-use management of pinyon-juniper from a Bureau of Land Management perspective. In: Everett, Richard L., comp. *Proceedings—pinyon-juniper conference*; 1986 January 13-16, Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 480-493.

Spencer, John S. Jr.; Smith, W. Brad.; Hahn, Jerold T.; Raile, Gerhard K. 1988. Wisconsin's Fourth Forest Inventory, 1983. *Resource Bulletin NC-107*. U.S. Department of Agriculture, Forest Service, North Central Experiment Station. St. Paul, MN. 48 p.

St. Aubin, K.; Massie, S. 1987. The abandoned mine land program. Springfield, IL: Association of Abandoned Mined Land Programs. 28 p.

Stoddart, Laurence A.; Smith, Arthur D.; Box, Thadis W. 1975. *Range management*. New York: McGraw-Hill Book Company. 532 p.

Stone, Charles P.; Scott, J. Michael. 1987. Hawaii's terrestrial ecosystems: preservation and management. In: *Proceedings of a symposium*; 1984 June 5-6, Hawaii Volcanoes National Park. Honolulu, Hawaii: University of Hawaii Press for Cooperative National Park Resources Study Unit. 584 p.

Swift, Bryan L. 1984. Status of Riparian ecosystems in the United States. *Water Resources Bulletin*. 20:223-228.

Thilenius, John F. 1975. Alpine Range management in the Western United States—principles, practices, and problems: The status of our knowledge. *Res. Pap. RM-157*. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 32 p.

Tiner, R.W., Jr. 1984. *Wetlands of the United States: current status and recent trends*. U.S. Fish and Wildlife Service. 59 pp.

Thill, Ronald E.; Wolters, Gale L. 1979. Cattle production on a southern pine-hardwood forest. *Rangelands*. 1:60-61.

Thill, Ronald E. 1983. Deer and cattle forage selection on Louisiana pine-hardwood sites. *Research Paper SO-196*. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 35 p.

Turner, George T.; Paulsen, Jr., Harold A. 1976. Management of mountain grasslands in the central Rockies: the status of our knowledge. *Res. Pap. RM-161*. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 24 p.

U.S. Department of Agriculture. 1989. *Conservation Reserve Program: Progress report and preliminary evaluation of the first two years*. U.S. Government Printing Office. Washington, DC. 98 pp.

U.S. Department of Agriculture, Economic Research Service. 1987. Projections of urban land. Attachment to May 6, 1987 memo from Klaus Alt to Basic Assumptions Working Group. Washington, DC.

U.S. Department of Agriculture, Forest Service. 1967. Section 74: Geographic forest types. In: *Forest survey handbook 4813.1*. Washington, DC: U.S. Government Printing Office. 74-74.2-3.

U.S. Department of Agriculture, Forest Service. 1969. *A forest atlas of the South*. New Orleans, LA: Southern Forest Experiment Station; and Asheville, NC: Southeastern Forest Experiment Station. 27 p.

U.S. Department of Agriculture, Forest Service. 1977. *A directory of research natural areas on federal lands of the United States of America*. Federal Committee on Ecological Reserves. Washington, DC: U.S. Department of Agriculture, Forest Service. 280 p.

U.S. Department of Agriculture, Forest Service. 1979. *An assessment of the forest and range land situation in the United States*. Washington, DC: U.S. Department of Agriculture, Forest Service. 352 p.

U.S. Department of Agriculture, Forest Service. 1980. *A statistical history of tree planting in the South, 1925-1979*. Misc. Report SA-MR8. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry. 37 p.

U.S. Department of Agriculture, Forest Service. 1981. *An assessment of the forest and rangeland situation in the United States*. Forest Service Resource Rpt. 22. Washington, DC. 631 p.

U.S. Department of Agriculture, Forest Service. 1985. *Mining in the national forests*. Current Information Report 14. Washington, DC: U.S. Department of Agriculture, Forest Service. 18 p.

U.S. Department of Agriculture, Forest Service 1987. *Basic Assumptions for the 1989 Forest Service RPA Assessment and 1986 Soil Conservation Service RCA Appraisal*. [No report number.] Washington, DC.

U.S. Department of Agriculture, Forest Service. 1988. Table developed by Minerals and Geology Management Staff, "Commodity production for all regions." [Copy available from USDA, Forest Service, Minerals and Geology Management Staff, P.O. Box 96090, Washington, DC 20090-6090].

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. Washington, DC: U.S. Department of Agriculture, Forest Service. 500 p.

U.S. Department of Agriculture, Forest Service. [In press]. A timber assessment—past, present, and future—in the U.S. forest sector. Washington, DC: U.S. Department of Agriculture, Forest Service.

U.S. Department of Agriculture, Soil Conservation Service. 1982. Basic statistic, 1982 National Resources Inventory. Iowa State University Statistical Laboratory, Statistical Bulletin No. 756. 64 p.

U.S. Department of Agriculture, Soil Conservation Service 1987. The second RCA Appraisal. Soil, water, and related resources on nonfederal land in the United States: Analysis of condition and trends. Review Draft. U.S. Department of Agriculture. Washington, DC.

U.S. Department of Energy. 1985. National energy policy plan projections to 2010. Washington, DC: U.S. Government Printing Office. 132 p.

U.S. Department of Energy. 1987. Annual energy review: 1986. Washington, DC: U.S. Department of Energy, Energy Information Administration. 293 p.

U.S. Department of Interior, Bureau of Land Management. 1987. Public land statistics: 1986. Washington, DC: U.S. Department of Interior, Bureau of Land Management. 120 p.

U.S. Department of Interior, Bureau of Mines. 1985. Minerals facts and problems: 1985 edition. Washington, DC: U.S. Government Printing Office. 956 p.

U.S. Department of Interior, Bureau of Mines. 1987a. 1985 minerals yearbook, vol. 2: area reports, domestic. Washington, DC: U.S. Government Printing Office. 635 p.

U.S. Department of Interior, Bureau of Mines. 1987b. Mineral commodity summaries. Washington, DC: U.S. Government Printing Office. 189 p.

U.S. Department of Interior, Fish and Wildlife Service. 1988. The impact of federal programs on wetlands. Report to Congress. Vol. 1. 114 p.

U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement. 1987. Surface coal mining reclamation: 10 years of progress, 1977-1987. Washington, DC: U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement. 49 p.

U.S. Environmental Protection Agency. 1987. Unfinished business—a comparative assessment of environmental problems: overview report. Washington, DC: United States Environmental Protection Agency. 100 p.

Ulrich, Roger S. 1981. Natural versus urban scenes, some psychophysiological effects. *Environment and Behavior* 13: 523-556.

Ulrich, Roger S. 1984. View through a window may influence recovery from surgery. *Science*. 224:420-421.

Verner, Jared; Boss, Allan S., tech. coordinators. 1980. California wildlife and their habitats: Western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 439 p.

Waddell, Karen; Oswald, David D. 1986. The national RPA timber database—Data dictionary and supporting documentation. Mimeo. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station mimeo. 66 p.

Wagstaff, Fred J. 1987. Economics of managing pinyon-juniper lands for woodland products. In: Everett, Richard L., comp., *Proceedings—Pinyon-Juniper conference*; 1986 January 13-16, Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 168-173.

Wakimoto, Ronald H.; Menke, John W. 1978. Measuring chaparral fuels. *California Agriculture*. 32(10): 15-16.

Wani, M.C.; Taylor, H.L.; Wall, Monroe E. 1971. Plant antitumor agents. VI. The isolation and structure of taxol, a novel antileukemic and antitumor agent from *Taxus brevifolia*. *Journ. of the American Chemical Society*. 93(9): 2325-2327.

Wenner, Lambert N. 1984. Minerals, people, and dollars: social, economic, and technological aspects of mineral resources development. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, 139 p.

West, N. E. 1983a. Great Basin-Colorado Plateau sagebrush semi-desert. In: West, Neil W., ed. *Temperate deserts and semi-deserts. Ecosystems of the World* 5. Amsterdam, The Netherlands: Elsevier Scientific Publishing Co.: 331-349.

West, N. E. 1983b. Western Intermountain sagebrush steppe. In: West, Neil W., ed. *Temperate deserts and semi-deserts. Ecosystems of the World* 5. Amsterdam, The Netherlands: Elsevier Scientific Publishing Co.: 351-374.

Whiting, R. Montague, Jr; Fleet, Rovert R. 1987. Bird and small mammal communities of loblolly-shortleaf pine stands in east Texas. In: *Physical and socioeconomic relationships within southern National Forests: Proceedings of the Southern Evaluation Project workshop*; 1987 May 26-27, Long Beach, MS. Gen. Tech. Rep. SO-68. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Wolters, Gale L.; Martin, Alton; Pearson, Henry A. 1982. Forage response to overstory reduction on loblolly-shortleaf pine-hardwood forest range. *Journal of Range Management* 35:443-446.

Wright, Henry A.; Bailey, Arthur W. 1982. *Fire Ecology*. New York, NY: John Wiley and Sons. 501 p.

Young, James A.; Evans, Raymond A.; Eckert, Jr., Richard E.; Kay, Burgess L. 1987. Cheatgrass. *Rangelands*. 9:266-270.

## APPENDIX A AREA PROJECTION METHODS

### Methods For Projecting Area Changes by Major Land Uses

Methods for projecting area changes for major land uses and associated waters in past Assessments primarily involved expert opinion approaches. Projections of area changes by land use for most regions in the 1989 Assessment were derived from a blend of (1) econometric analysis of historical relationships among major land uses and key variables (e.g., Alig 1986) and (2) expert opinions. This blend is necessary because land use changes involve a complex interaction of factors, and in some cases research is still underway in attempting to quantify the relationships among such factors. This approach involves the application of total land base constraints so that areas in all uses must sum to the total land area. Specific methods used for each region are described in more detail by Alig et al. (1989).

Improved resource and ownership data have allowed estimation of econometric models of land allocation that allow simultaneous, dynamic consideration of competing uses. Quantitative models are available for some regions to investigate the forces that underlie changes in forest and range area and to use them for projections.

Modeling area changes for land uses and ownerships in each region proceeded in two stages. In the first stage, net area changes for all major land uses/forest ownerships were projected simultaneously to assure that fixed land base constraints were met. Projections of public forest and range area were external to the model and were based on the expert opinions of agency personnel and other experts knowledgeable about the management and acquisition of public land in each region.

In the second stage of the area modeling, which only involves timberland, area changes were projected for forest management types by forest ownership. Area changes for forest management types reflect influences of both natural successional forces and land management activities or disturbances (Alig and Wyant 1985). Projections of area changes by management types are important because they reflect differences in management practices among ownerships and among states. They directly reflect tree planting, one of the chief indicators of management intensity.

Factors influencing private land use conversion, forest type transition, and the sources and quality of data vary greatly among regions. Because of this, models were developed individually for each region, and are described separately for each region by Alig et al. (1989).

Projections of area changes for major private land uses are based on the theory that private land tends to be used for the purpose that produces the economic maximum (including financial and nonfinancial benefits) for the

owner. Thus the best use of land is largely determined by the expected difference discounted back to the present between the value of the output and the cost of production for alternative uses. Because costs, prices, and techniques of production change over time, so does the optimal use of land. A good historical example of this is the abandonment of the wheat farms in northern Wisconsin after the increase in production in the Great Plains and the corresponding decline in the price of wheat.

Results from research studies for the North (Plantinga et al. 1988, Howard and Lutz 1989), South (Alig 1985), and Pacific Coast (Parks 1986, 1988a; Berck and Parks 1987) sections, along with some input based on expert opinions, were used to develop regional area projection models. Series of econometric equations were developed to project area in crops, pasture/range, urban/other, industrial forest, and farm and miscellaneous private forest uses. Expert opinion approaches were used for the Rocky Mountains and Alaska. Input data for the dependent variables were collected from the USDA Forest Service Forest Inventory and Analysis (FIA) units. The initial 1987 acreage data for all land classes were obtained from the RPA data base (Waddell and Oswald 1986).

Equations from regional research studies (e.g., Howard and Lutz 1989), which had land uses or forest ownership areas as the dependent variables, were incorporated into a projection system similar to that described by Alig (1985). If a research-based equation for a particular non-forest use was not available, projections of area changes for those uses—crops, pasture/range, or urban and other lands—were constructed from existing studies (e.g., urban area projections by the USDA Economic Research Service (1987) and Alig and Healy (1987)) or expert opinion, augmented by analysis of data series (e.g., Frey and Hexem 1985) on land use changes.

Projections of changes in forest area for the South are consistent with those for the recent comprehensive study of the forest resource supply situation in the South (USDA Forest Service 1988). It should be noted that Kentucky has been added here to the 12 states examined in the Southern Study and the area projections include lands under long-term lease by forest industry was part of the nonindustrial ownership class (such acres were included under the industry class in the Southern Study).

Projections of area change for rangeland were a blend of exogenous projections from the National Interregional Agricultural Production (NIRAP) model, adjusted for likely land use impacts of the CRP (Joyce 1989). NIRAP's projections of land use change are based primarily on extrapolation of historical trends. About 40 million acres

of highly erodible cropland are expected to be placed in grass cover under the CRP nationwide, and some of this acreage may revert naturally to rangeland or forest over time. Most of the natural reversion to rangeland occurs between 1990 and 2000. The range area projections were included as part of the basic assumptions developed by the USDA Forest Service and SCS (USDA Forest Service 1987). A related assumption is that some type of conservation reserve program will remain in effect throughout the projection period.

The only exception to this projection process is that urban areas and public areas are accepted as given and were not subjected to any necessary adjustments to meet total land base constraints. A hierarchical approach dictated that urban and developed uses were dominant in the land allocation according to the conversion pressures, related to the much higher land prices that urban and developed uses command compared to agricultural and forestry uses. Such developed uses are essentially irreversible in the foreseeable future and the trend in their area is upward. Changes in public forest and range area are relatively stable in general compared to private timberland, and were incorporated as a fixed vector.

Area projections for public ownerships (e.g., state, BLM) were made by agency personnel in regional offices. For example, area projections for national forest land of the USDA Forest Service for all regions reflect the forest planning process (Alig et al. 1989). Projections include any timberland withdrawals for likely wilderness areas, roads, powerlines, reservoirs, and associated uses.

A variety of assumptions were used to project the diverse set of variables that influence private land use changes in the projection system. Because highly accurate predictions of these independent variables for several decades into the future are not possible, reasonable assumptions were made based on historical trends, developments that affect those trends, and the expectations regarding future changes. Assumptions used in making projections for population, personal income, and inflation rates are those used for the 1989 RPA Assessment and 1986 RCA Appraisal (USDA Forest Service 1987).

Many of the forces that have caused the recent changes in area of forest and rangeland will surely continue to influence changes in the future. Thus, in making projections of area changes, it has been assumed that determinants such as population, income, agricultural productivity, agriculture exports, and prices of agricultural crops and timber products would continue to influence land use changes (Alig 1985).

Assumptions pertaining to the future rate of change in agricultural productivity and associated land incomes were derived from the 1986 RCA Appraisal (USDA Soil Conservation Service 1987). RCA assumptions on the annual rate of increase in yield vary by crop, but the rate of increase up to the year 2000 is higher in all cases than the increase projected from 2001 to 2030. For example, productivity for field crops was assumed to increase by 1.9 percent annually up to the year 2000 and then slow down to 1.2 percent annually. Real product prices for

agricultural products were assumed to remain essentially constant over the projection period. Slow increases in the export of agricultural products are projected. Livestock incomes were projected assuming constant real prices and no changes for productivity growth.

Stumpage price projections used in the land use modeling are those generated by the Timber Assessment Market Model (TAMM) for the 1989 RPA Assessment. Interaction with TAMM allows projected changes in timberland area to respond to economic forecasts.

The models project area changes for timberland by owner group (industry, farmer, and miscellaneous private), pasture/rangeland, and urban/other land. Changes in the area of timberland—land capable of growing at least 20 cubic feet of industrial wood per acre per year and not reserved for other uses—are major determinants of changes in net annual growth, inventory, and other components of the forest resource. A large percentage of private forest land is classified as timberland, and future total area trends for these two land base descriptions are likely to be similar.

Changes in land area are input to projection models (e.g., timber inventory projection) for different forest and rangeland resources each decade. For example, natural afforestation or active regeneration are additions to young age classes in timber inventory modeling (Parks and Alig 1988). Land clearing or harvest without subsequent regeneration may remove acres from the inventory.

At least three groups of input data are required for the area change projection models: (1) cross-section or time series data to estimate model parameters; (2) current land use data or descriptions of the forest land base from FIA remeasurements, and (3) projections of predetermined variables. The first two groups are necessary to estimate the models; the third is necessary to simulate future area changes for land uses.

Preliminary projections of forest and range area derived from the econometric system and the assumptions described above were modified in response to reviews by the state forestry agencies, industry representatives, public land management agencies, and other experts in each region. The system and the projections were also reviewed by technical experts from the Forest Service, forest industries, and forestry schools.

### Methods For Projecting Area Changes by Forest Type

Changes in area among forest types affect both the nature and volume of timber available from forests. For example, decreases in timber production can occur when commercial species are crowded out by noncommercial species. Failure to account for these forest type changes can lead to unjustified optimism about future timber production. In addition, forest type changes are important when assessing prospective supplies of other forest resources.

Forest type transitions are simulated by multiplying an initial vector of acres by forest type by a transition probability matrix. The matrix of transition probabilities

is generated by multiplying a vector of disturbance probabilities by a matrix of conditional probabilities for transitions among forest types, each with the general form:

$$P(D_{k(i,j,t)}) P(FT_{i,j',t+1} | D_{k(i,j,t)}, FT_{i,j,t}).$$

This represents the probability (P) of a disturbance (D) of type k on ownership i and forest type (FT) j in decade t multiplied by the conditional probability that a unit area of timberland on ownership i at decade t + 1 will be in forest type j', given the disturbance (Alig and Wyant 1985). These probabilities are derived from sample relative frequencies of remeasured Forest Service inventory data, classified into three disturbance

categories (no management, regeneration harvest, and miscellaneous) and three ownership groups (farmer, miscellaneous private, and industry).

If no data on disturbances are available and plots have been remeasured at least once, the simpler probabilities

$$P(FT_{i,j',t+1} | FT_{i,j,t})$$

which are an average over all disturbance regimes (including no disturbance) and owner groups, could still be estimated from sample relative frequencies. This projection framework was applied, in conjunction with adjustments suggested by the respective FIA units, for the North Central region (Parks 1988b) and Pacific Northwest Westside (Parks 1988c).

## Glossary of Land Area Terms used in the Analysis

**Bureau of Land Management (BLM)**—An ownership class of federal lands administered by the Bureau of Land Management, U.S. Department of the Interior.

**Commercial species**—Tree species suitable for industrial wood products.

**Douglas-fir subregion**—The area in the states of Oregon and Washington that is west of the crest of the Cascade Range.

**Ecological status**—The degree of similarity between the present community of a site. Considers only secondary succession.

**Farmer**—An ownership class of private lands owned by a person who operates a farm, either doing the work himself or directly supervising the work.

**Federal**—An ownership class of public lands owned by the U.S. Government.

**Forest industry**—An ownership class of private lands owned by companies or individuals operating wood-using plants.

**Forest land**—Land at least 10% stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10% stocked with forest trees, and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West, and afforested areas. The minimum area for classification of forest land is one acre. Roadside, streamside, and shelterbelt strips of timber must have a minimum crown width of 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet in width.

**Forest trees**—Woody plants having the potential for one erect perennial stem or trunk at least 3 inches in diameter at breast height (dbh) or 4-1/2 feet, a more or less definitely formed crown of foliage, and a height of at least 16 feet.

**Forest type**—A classification of forest land based upon the species presently forming a plurality of the live-tree stocking. Synonymous to forest ecosystem.

**Growing stock**—A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, includes only trees 5.0-inches dbh and larger.

**Hardwood**—A dicotyledonous tree, usually broad-leaved and deciduous.

**Land area**—(a) Bureau of Census: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river food plains; streams, sloughs, estuaries, and canals less than 1/8 statute mile wide; and lakes, reservoirs, and ponds less than 40

acres in area. (b) Forest Inventory and Analysis: same as (a) except that the minimum width of streams, etc., is 120 feet, and the minimum size of lakes, etc., is 1 acre. This latter definition is the one used in this publication.

**National Forest (NF)**—An ownership class of Federal lands, designated by Executive Order or statute as National Forests or purchase units, and other lands under the administration of the Forest Service including experimental areas and Bankhead-Jones Title III lands.

**Nonforest land**—Land that has never supported forests and lands formerly forested where timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 40-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., more than 1 acre in size, to qualify as nonforest land.)

**Nonstocked areas**—Timberland less than 10% stocked with growing-stock trees.

**Other federal**—An ownership of federal lands other than those administered by the Forest Service or the Bureau of Land Management.

**Other forest land**—Forest land other than timberland and reserved timberland. It includes unproductive forest land, which is incapable of producing annually 20 cubic feet per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness. It also includes urban forest land, which due to its location is unavailable for sustained timber harvesting.

**Other land**—Nonforest land less the area in streams, sloughs, estuaries, and canals between 120 and 660 feet wide and lakes, reservoirs, and ponds between 1 and 40 acres in area (i.e., nonforest land less non-Census water area).

**Other private**—An ownership class of private lands that are not owned by forest industry or farmers.

**Other public**—An ownership class that includes all public lands except National Forest.

**Ownership**—The property owned by one ownership unit, including all parcels of land in the United States.

**Ownership unit**—A classification of ownership encompassing all types of legal entities having an ownership interest in land, regardless of the number of people involved. A unit may be an individual; a combination of persons; a legal entity such as a corporation, partnership, club, or trust; or a public agency. An ownership unit has control of a parcel or group of parcels of land.

**Ponderosa pine subregion**—The area in the states of Oregon and Washington that is east of the crest of the Cascade Range.

**Productivity class**—A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

**Rangeland**—is a type of land on which the native vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs. Rangelands include natural grasslands, shrublands, savannas, most deserts, tundra, alpine plant communities, coastal marshes, and wet meadows. Plant communities dominated by introduced species that are managed like rangeland are also included in this type of land. Rangeland also includes many riparian vegetation types.

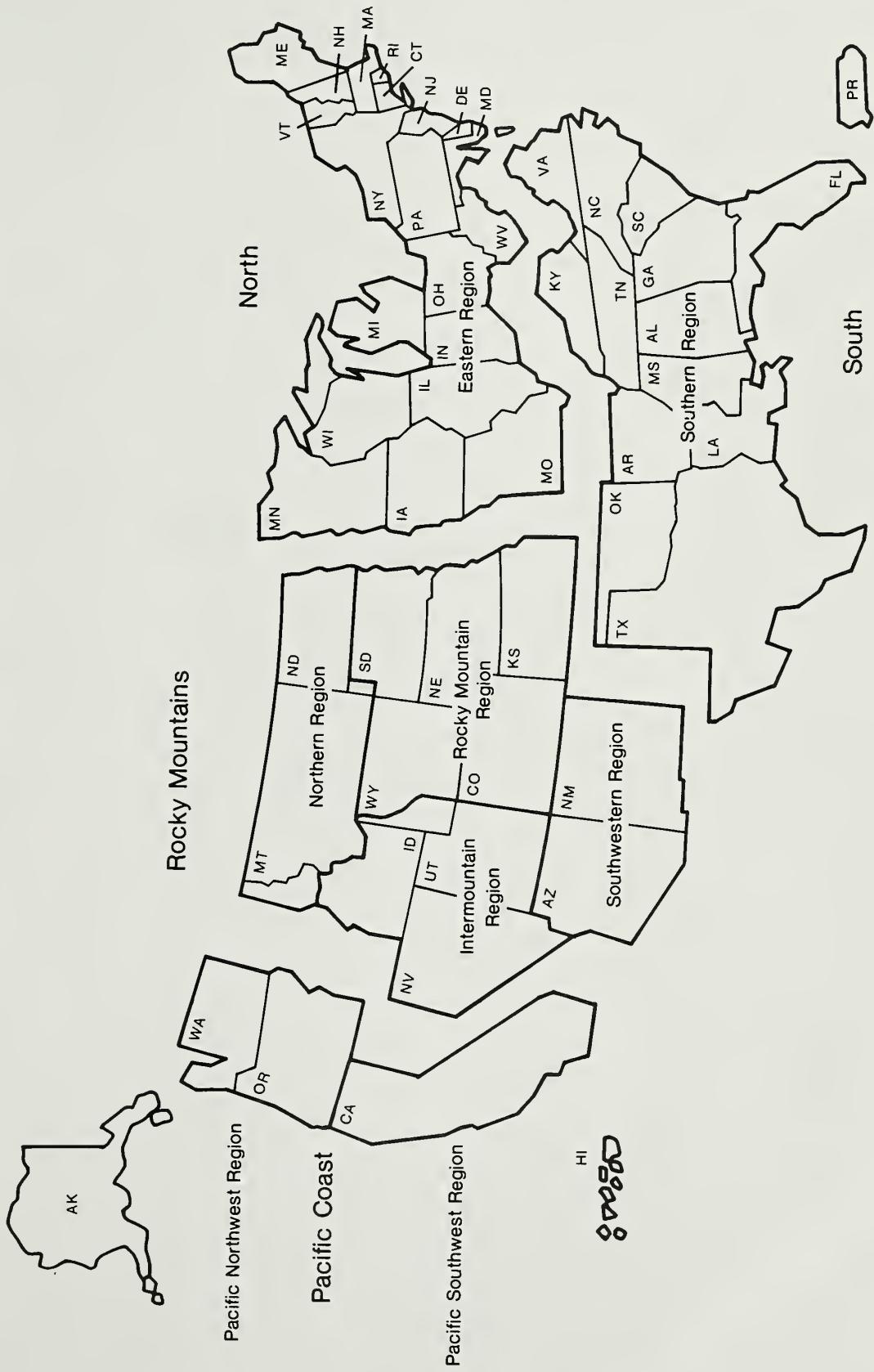
**Reserved timberland**—Forest land that would otherwise be classified as timberland except that it is withdrawn from timber utilization by statute or administrative regulation.

**Softwood**—A coniferous tree, usually evergreen, having needles or scalelike leaves.

**State**—An ownership classification of public lands owned by states or lands leased by states for more than 50 years.

**Timberland**—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note; Areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

# Forest Service Regions and Assessment Regions





\* NATIONAL AGRICULTURAL LIBRARY



1022290233

NATIONAL AGRICULTURAL LIBRARY



1022290233